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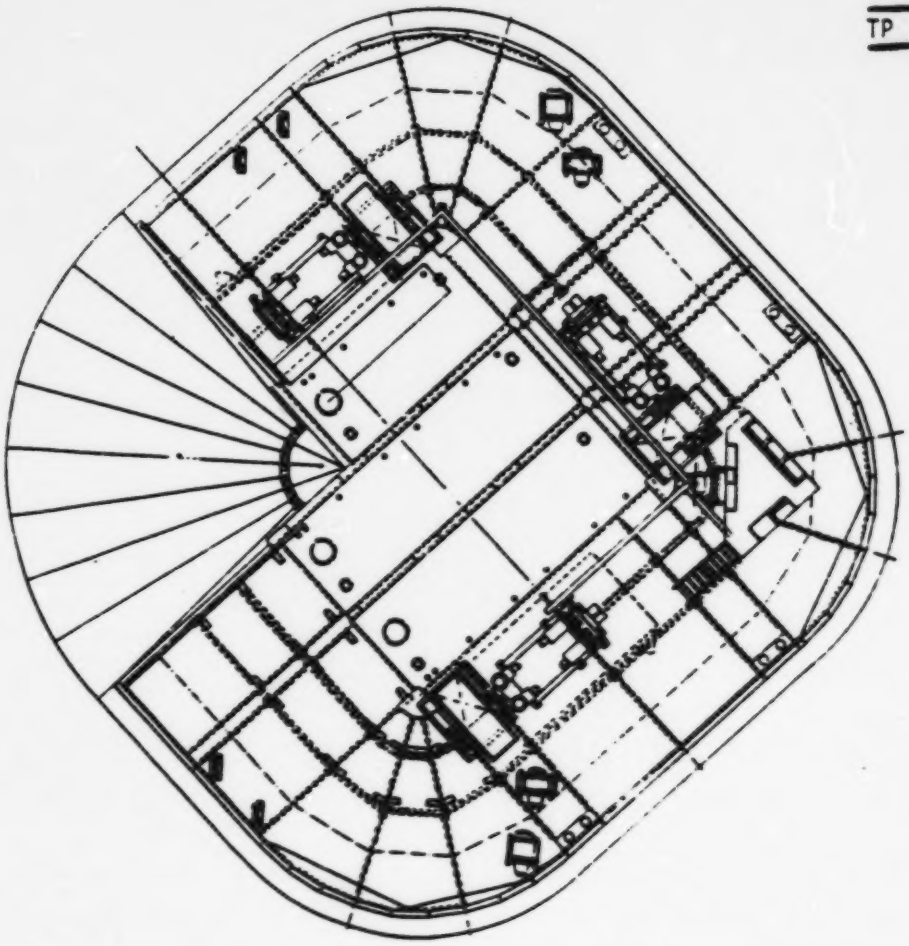

FINAL ANALYSIS OF INTERIM NOTCH SEAL AND SYSTEMS MODIFICATIONS AIR CUSHION ICE-BREAKING BOW HSL-533

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FINAL ANALYSIS OF INTERIM NOTCH SEAL AND SYSTEMS MODIFICATIONS AIR CUSHION ICE-BREAKING BOW HSL-533

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PREPARED FOR

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TRANSPORT CANADA, MONTREAL

BY

G.R. TOTHILL AND A.Y. SIMPSON
BELL AEROSPACE CANADA TEXTRON
GRAND BEND OPERATIONS

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PROJECT TEAM

The project team for Bell Aerospace Canada Textron was composed of:

Mr. G.R. Tothill	-	Grand Bend
Mr. M.J. deBlieck	-	Grand Bend
Mr. A.R. Resch	-	Grand Bend
Mr. R.G. Moore	-	New Orleans
Mr. J.M. Ryken	-	New Orleans
Mr. A.Y. Simspon	-	New Orleans
Mr. J. Goffredo	-	New Orleans

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17 Abstract

This project is part of the activities related to testing and evaluation of the Canadian Coast Guard air cushion ice-breaking bow (ACIB) at Thunder Bay during the winter of 1981/82.

A complete analysis, from original drawings, was done of the ACIB structure, seal and lift systems, fuel system, winch control system, and electrical system. Necessary changes were made within the guidelines given, in order to allow the craft to operate during the 1981/82 ice-breaking season.

Upon completion of assembly and overland testing of the systems the ice-breaking tests commenced. Due to the extremely short period of time remaining before natural ice break-up only very limited ice-breaking tests could be carried out. The various components of the complete craft structure, notch seal, lift, and systems were evaluated. The general conclusions from the evaluation are that the chosen method of supporting the notch fingers by means of hinged steel trusses is viable, and may be superior to the so-called "soft" approach where the notch fingers are self-supporting. This would not be the case, however, if the notch size could be drastically reduced.

It is recommended that modifications to the craft during 1982 be kept to a minimum. This would allow more time and a greater portion of the budget resources to be devoted to thoroughly testing the current design before modifying the craft for operational service.

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Ice-breaking, air cushion, air cushion ice-breaking bow, ACIB, notch seal	Limited number of copies available at TDC

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	N.E. Rudback

17 Résumé

Ce projet entre dans le cadre des travaux relatifs à l'essai et l'évaluation de la proue brise-glace à coussin d'air de la Garde côtière canadienne, exécutés à Thunder Bay durant l'hiver de 1981/82.

Une analyse exhaustive a été faite, à partir des plans d'origine, de la structure de cette proue, de la liaison proue/navire, du système à coussin d'air, du circuit d'alimentation, du treuil et du circuit électrique; des modifications ont été faites conformément aux directives données, afin de rendre la proue apte aux opérations de déglaçage dès l'hiver 1981/82.

Une fois la proue assemblée et les essais terrestres faits, les essais de déglaçage proprement dits ont commencé. Mais, ils ont été fortement limités dans le temps en raison de la proximité de la fin de l'hiver et le commencement de la débâcle. Cependant, les divers composants de la proue: structure de liaison, système à coussin d'air et divers autres systèmes, ont pu être intégralement évalués. Ces travaux ont conduit à la conclusion que la méthode choisie pour supporter les segments à l'aide de poutres en acier à charnières est la bonne et même qu'elle surclasse la méthode précédemment utilisée, dans laquelle les segments étaient autoporteurs. Cette dernière méthode aurait pu convenir si les segments avaient été de superficie moindre. Le rapport recommande de ne faire en 1982 que les modifications strictement nécessaires, de manière à laisser plus de temps, et de consacrer une plus grande part du budget aux travaux d'essais exhaustifs de la proue dans sa conception actuelle, laissant à plus tard les travaux d'adaptation aux exigences du service.

18 Mots-clés	19 Diffusion
Déglaçage. Coussin d'air. Proue brise-glace à coussin d'air. Structure de liaison.	Le CDT dispose d'un nombre limité d'exemplaires.

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SUMMARY

The objective of this project was to convert conceptual designs for an interim notch seal on the Canadian Coast Guard air cushion ice-breaking bow (ACIB) into detailed designs suitable for hardware construction. These modifications were to be carried out using as much of the existing design, materials and structures, as possible. In all cases the governing directive was to make the minimum change required in order to enable the craft to operate during the 1981/82 ice-breaking season.

This objective was met, but not without some changes and unexpected additional work. For instance, the changeover from the CCG Griffon to the CCG Alexander Henry resulted in placing the notch finger support structure inside the fingers rather than above them, as in the original plan. Strengthening the carrousel structure to carry the very large upwards loads generated by the notch fingers resulted in greater difficulties than expected, as did the installation of the truss work and fingers in severe winter conditions.

In spite of these problems, the ACIB successfully underwent two ice-breaking trials and gathered sufficient data to support a preliminary evaluation of the ACIB platform. Some minor problems were apparent during the trials and these are discussed in the report, together with recommendations for future trials and development work.

The general conclusion from this work is that the chosen method of temporarily supporting the notch fingers is viable and capable of development, and may be superior to the so-called "soft" approach where the notch fingers are self-supporting. This would not be the case, however, if the notch size could be drastically reduced.

FINAL ANALYSIS OF INTERIM NOTCH SEAL AND SYSTEMS MODIFICATIONS AIR CUSHION ICE-BREAKING BOW HSL-533

SUMMARY

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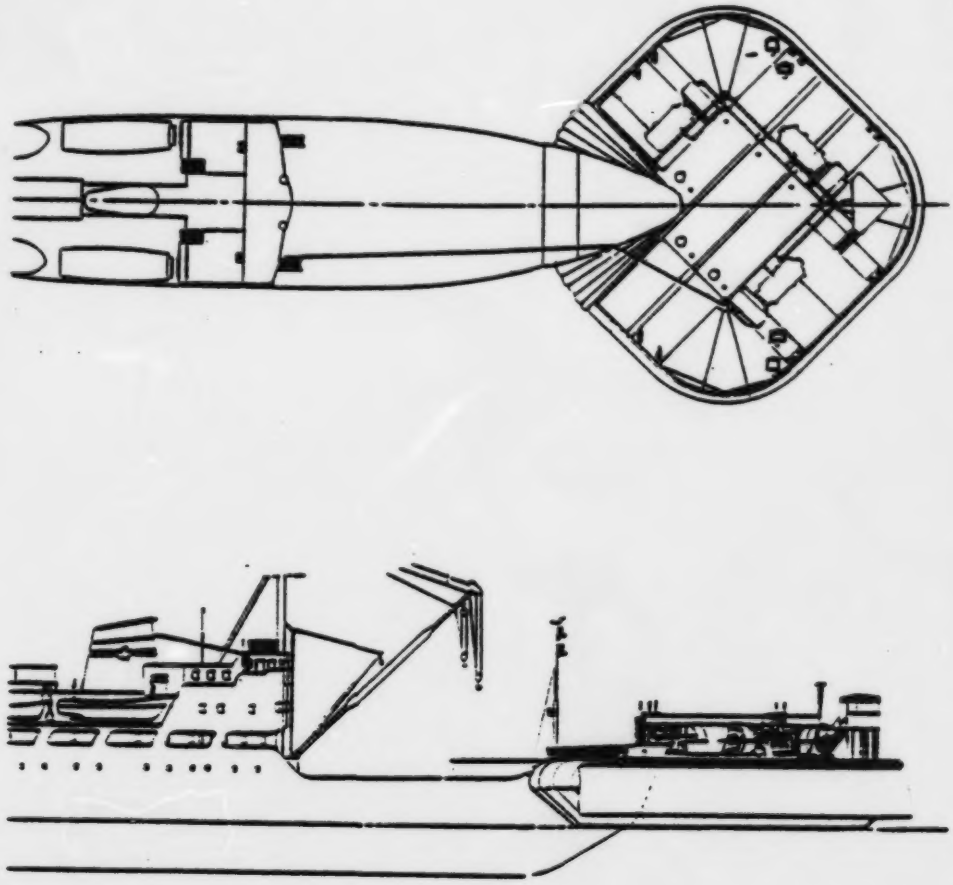


ICE-BREAKING BOW ATTACHMENT

1. INTRODUCTION

This report discusses the Phase II engineering changes made by Bell Aerospace Canada Textron (BACT) to the Air Cushion Ice-Breaking (ACIB) Bow Platform HSL-533, the manner in which these changes were implemented, and the results of the initial ice-breaking trials conducted by TDC towards the end of April 1982, made possible by these changes.

Bell made a preliminary evaluation of the ACIB in 1981 (Phase I report, Ref. 1) in which a number of recommendations were made for a minimum of redesign effort necessary to prepare the platform for the 1981/1982 ice-breaking trials. These recommendations were evaluated by TDC and BACT and those changes required for the test program were incorporated onto the ACIB. In addition to the recommendations made in the preliminary report, it became apparent that some redesign effort would be required on the fueling system, the winch controls, and the engine controls.

The decision to use the CCG Alexander Henry in the trials necessitated re-running the model tests, conducted in Phase I with the CCG Griffon, with a bow model of the Alexander Henry. As a result, the exterior truss work had to be replaced with articulated trusses located inside the notch fingers. The latter were left unmodified initially due to the severe schedule restrictions. Improper installation resulted in difficulties and failures in the notch fingers which required some fabric additions to the notch fingers to ensure adequate strength.

Two series of ice-breaking trials were conducted by TDC before closing the operation for the summer. The modifications to the notch seals and other equipment on-board functioned adequately, enabling the ACIB to perform as originally planned.

2. DISCUSSION

2.1 Phase I Recommendations

It was concluded at the end of the first phase of the program that the existing ACIB could be modified sufficiently and in time to allow ice-breaking trials to be conducted in the winter of 81/82. To meet this goal, a number of recommendations were made for the follow-on work. The most significant of these was the recommendation to conduct additional model tests with the Alexander Henry bow module exchanged for the Griffon.

A 1/10th scale test rig, which included the notch seal area and bow portion of the CCG Griffon, had been constructed and tested during the first phase of the program (see Reference 1 for a description). The Griffon was chosen because of its large bow half angle of 43° and the possibility of its use during the upcoming full scale trials. However, the CCG Alexander Henry was selected.

With the new model it was immediately apparent that the size of the half angle was by no means the only design criteria. While the Alexander Henry's half angle is only 37.5°, other factors, such as stem bluntness and flair, led to a very poor sealing condition along the hull sides. The last truss made only point contact and held the notch fingers away from the ship over a large portion of their length. A seal of sorts could be made below the trusses, but the inflated geometry was highly

distorted and would have given rise to unpredictable stress concentrations. In addition, the bow flair geometry was such that the adjacent trusses were contacted along their upper members putting a severe twisting moment into the hinges.

Consequently, the only recourse open in the time remaining was to recommend reversion to the original idea of placing the trusses within the notch fingers. This change partially solved the problem. The remaining difficulties were overcome by adding hinges to the two inner trusses part way along their length in order to obtain an effective seal in all operating conditions. The new arrangement also had the advantage of removing the potential interference problem between the bow stem and truss support structure. Weight and cost savings were obtained from the ability to attach the trusses to internal members at a location where ice accretion is unlikely.

Apart from recommendations concerning the safety of the operating crew, the other point of major significance was the requirement to provide alternative air paths to the notch fingers during lift-off. It was concluded during the first phase that the notch fingers were in danger of being starved from sufficient air flow with the hull floating off-cushion in the water. Once off-cushion, the ACIB might not be able to regain cushion without considerable outside assistance.

2.2 Model Development

The initial objective of the model test program with the Alexander Henry bow module was to develop an effective bow stem seal and to make sure the notch seal functioned correctly with the alternative bow. As explained above, additional modifications to the rig were necessary as a result of the change.

The notch seal arrangement of radially disposed closed fingers is not conducive to sealing off the area directly ahead of the bow stem. A special seal, or pair of seals, is necessary to close off this leakage area. It is expected that a universal seal can be designed to fit the complete range of Coast Guard vessels likely to be used with the ACIB. However, to ensure the best possible seal for the trials, a 1/10th scale model of the bow portion of the Alexander Henry was made to replace the Griffon model. At the same time, the rig was converted to the internal truss configuration with the extra hinges on the inboard trusses.

Up to this point, the full cushion and partial cushion modes had been obtained by locating the ground board at the required height with reference to the notch seal. To improve this capability and to represent similar operating conditions to that of coming on and off cushion, with and without the bow module, an inflatable device (truck inner tube) was inserted under the ground board to provide variable cushion height control.

2.3 Structural Design

2.3.1 Hull Modification

The decision to place the trusses inside the notch fingers and to locate the truss hinges on the existing finger attachment structure (carrousel)

removed the requirement for any additional deck structure. The original notch finger design was supposed to obtain structural stability of the fingers from a combination of weight in the form of sandbags and water-filled tubes and by bending moment reactions carried back into the carrousel. When the notch finger loads were applied to the main structure by the trusses, it was found that the carrousel was considerably below strength. Extensive modifications of the carrousel were necessary to carry the latest design loads safely. The additions and modifications to the existing carrousel are described in paragraph 3.1. The extent of the necessary modifications came as somewhat of a surprise, since the original notch finger loads transferred to the hull were not substantially altered by the addition of trusses. Due to the tight schedule defined by the closing winter season, there was not time for formal drawings of the carrousel modifications. Sketches and verbal instructions had to suffice.

2.4 Seal Design

2.4.1 Notch Seal

It was planned to carry the upward loads generated by the notch fingers through a series of "saddles" slung between the external trusses and to provide additional local ties to hold the fingers in place when deflated. The saddles were omitted with the internal truss design since all the loads could now be transferred into the trusses directly from the vertical walls of the fingers. Figure 2.4-1 shows both methods.

In the final design, the internal trusses were provided with full length attachment fittings so that the fabric loads could be taken out evenly. Additional attachments were provided at the outboard end of each finger where the loads increased due to the pie-shaped planform and from a degree of imbalance due to minimizing the truss length (see Appendix). If more time had been available, a bead type fitting would have been bonded to both seals along the attachment location.

The intended location of the attachments was to have been slightly below the theoretical tangency line of the fully inflated finger, without ship insertion, to ensure that vertical fabric loads were transferred to the trusses. In practice, a slight error occurred during the design which put the attachment line slightly above the theoretical tangency line. This had the effect of slightly reducing the overall inflation width of the fingers during the free inflation mode, tending to pull the inboard trusses apart. However, problems and alterations to the attachments occured during installation (see paragraph 4.3) which largely obscured this effect.

2.4.2 Stem Seal

The design requirements for the stem seal were that it should be self-inflating, reasonably insensitive to ship location with respect to the ACIB, and of simple construction and attachment design. These requirements were largely met in practice, since the seal was made from flat patterns and utilized existing attachment locations apart from small

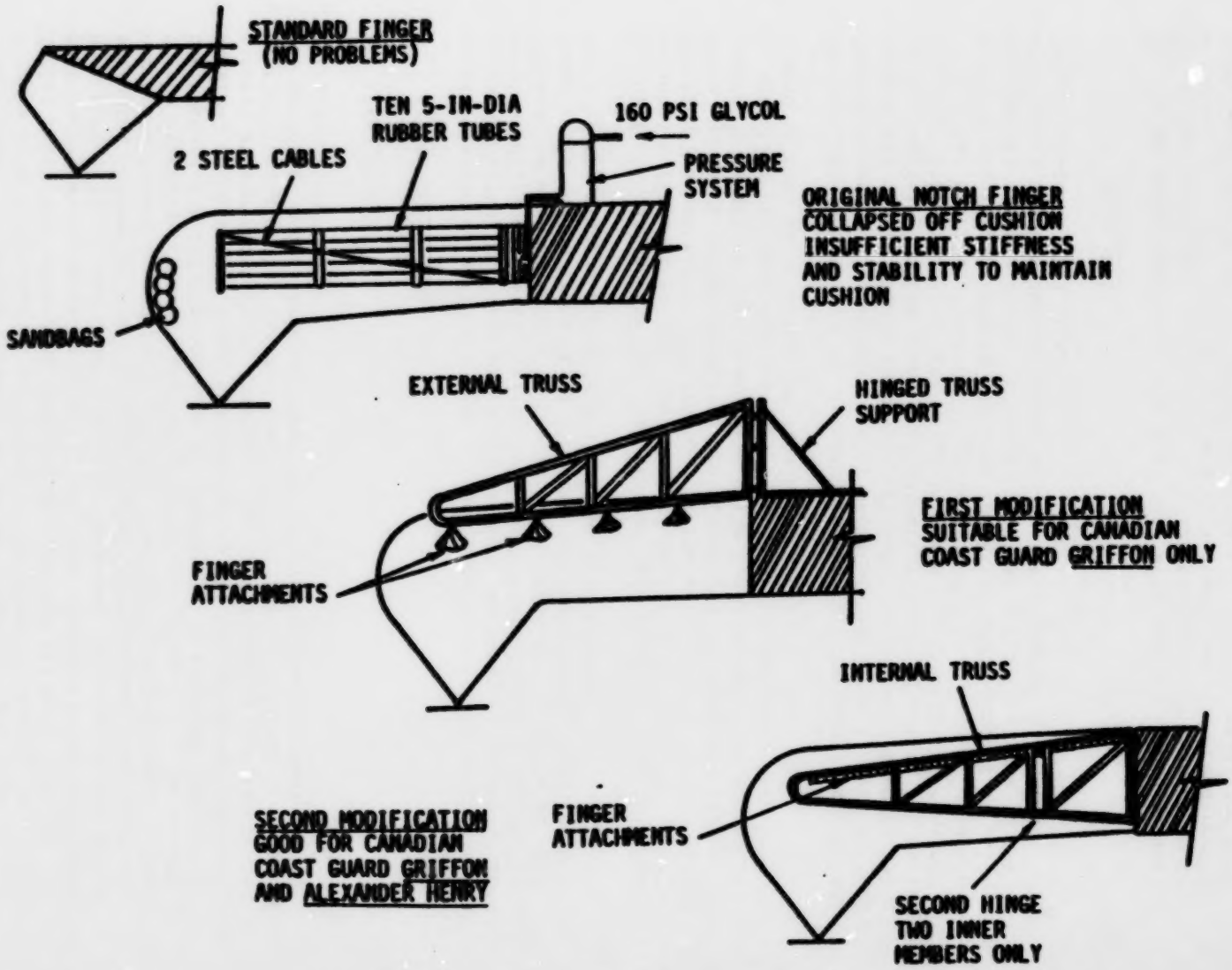


Figure 2.4-1 ICE-BREAKER SEAL SYSTEM DEVELOPMENT

modifications to existing deck brackets. Almost a 100% seal was obtained during rig tests with the ship fully inserted and an effective seal was maintained for approximately one to one and one half metres of ship separation before cushion pressure was lost.

2.5 Fuel System

The fuel system as originally designed was marginal in supplying the total quantity of fuel necessary to operate the engines for the 3 hours required by the contract. Also, difficulty would be encountered in attempting to fill the tanks due to the existing plumbing and venting system design. The original design proposed by BACT called for the fuel tanks to be filled from the centre of the fuel system. Due to the desire to use the existing plumbing, BACT was instructed to design the system to be filled from one end, thus filling the tanks sequentially.

2.6 Winch Controls

As this system had been wired in Calgary, the winches would not operate properly, although they had been operated by manually controlling the appropriate valves. It became apparent that the required hydraulic operation of the winch system be established before the electrical controls could be completed. Port Arthur Ship Building was tasked with this work and the required method of operation was supplied to BACT. The electrical winch control system was completed, based on the hydraulic requirements thereby provided.

2.7 Electric Systems

A complete analysis of the operation of each of the electrical systems was completed, in order to determine whether there existed any weakness in them. The requirement to effect as few changes as possible was used as a guideline in all cases where modification was necessary. For the most part, the electrical systems as originally designed were generally acceptable.

3. ANALYSIS

3.1 Structural Analysis

The notch structure is an all-welded CSA GS40.21 44T steel assembly consisting of two legs, both the upper and lower racks with cover plates, a K-frame, and vertical uprights to locate the pan assemblies which support the notch seals and trusses. This structure forms a circular-quadrant (see Figure 3.1-1) which is finally bolted and welded to the duotank and the tritank on the HSL-533 Air Cushion Ice-breaker.

The notch structure (carrousel) is the foundation for mounting eight notch seals and eight trusses. The geometries of a single notch seal finger and support truss are shown in Figure 3.1-2. The notch seals are made from flexible coated fabric and are finally bolted to the trusses and notch structure. The trusses are basically Pratt-trusses

made from 101.6 x 10.16 x 6.35 mm (4 x 4 x ¼") square tubing, CSA GS40.21, 44T steel. This steel has an ultimate tension strength of 448,000 kPa (65,000 PSI) and yield tension strength of 303,400 kPa (44,000 PSI). All joints are welded. Each truss includes mounting lugs at the innermost top and bottom joints, where they are hinged, with bolts, to each vertical pan assembly. Each hinge axis is oriented vertically, in-line so that each truss can rotate laterally, to permit matching the ACIB with the ship's bow.

In turn, each vertical pan assembly is bolted at the bottom to the lower rack with two, 31.75 mm (1.25 inch) diameter ASTM-A490 steel hex-head bolts; and two 15.88 mm (0.625 inch) diameter hex-head bolts of the same material connecting the pan to the newly installed vertical web with tee-stiffeners. The top end of each pan bears directly upon the upper rack of the notch structure.

Based on the maximum static pressure output from the fan, at an overspeed of 2,100 RPM, with inlets fully open, the maximum possible air cushion pressure, while the ACIB is rising up, is 15.86 kPa (2.3 pounds per square inch). This pressure is considered to extend to the most (radially) outboard point on each notch finger (Figure 3.1-3). This is a transient condition that might result from a human error, equipment malfunction or severe cushion bounce oscillation. It is a more severe design case than the 10.0 kPa (1.45 PSI) static condition, with a lower waterline, used for the original design of the HSL-533.

The overall net vertical force created by this pressure is 99,065 kPa (218,400 pounds), upward, and the overall horizontal couple-forces resisting the overturning moment produced by this force, relative to the notch racks, are approximately 207,300 kg (457,000 lbs.), tension at the bottom/compression at top.

Figure 3.1-4 presents the internal loads distribution in each notch finger truss, and the reactions from the upper and lower racks applied to each vertical pan. The critically loaded truss member is member DE, which is subjected to the combined actions of compression and bending, which results in a reserve factor of unity, or a margin of safety of zero, against yielding of a beam-column.

Based on the maximum loads from the notch finger trusses and upon conducting a detail strength analysis, it was found that the existing vertical pans and the existing notch structure were not structurally adequate to sustain those loads; as a result, each component was reinforced, as partially indicated in Figure 3.1-1.

The major reinforcement was made to the notch structure, wherein a vertically tee-stiffened web was incorporated between the upper and lower racks to resist the vertical shears from each truss, and transmit those shears to the notch legs which distribute the shears to the duotank and tritank, by way of the two 31.75 mm (1.25 inch) diameter hex-head bolts (A490 steel). The net horizontal couple-forces (207,300 kg) mentioned earlier, however, are resisted as in-plane shears by the 12.7 mm (½") (.50 inch) thick plate webs at the upper and lower racks. These heavy webs collect the resulting shears and transmit them across the welds (Figure 3.1-1) to the top and bottom covers of the duotank and the tritank.

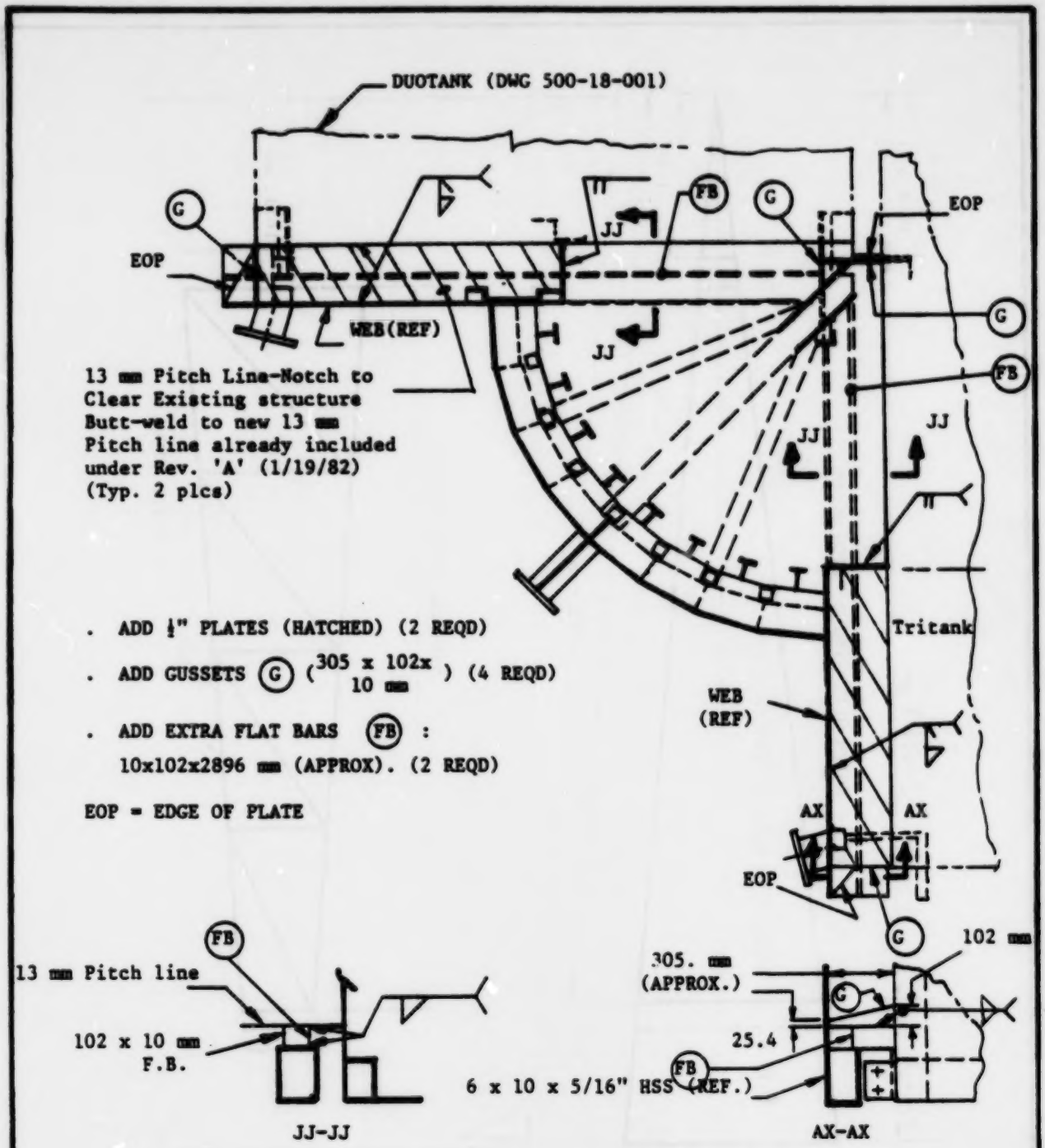


FIG. 3.1-1 PLAN VIEW, LOWER RACK, MODIFIED NOTCH STRUCTURE.
(REF. DWG. 533-18-009, REV. A, SHEET 2, SECTION B-B)
(UPPER RACK MODIFICATION SIMILAR)

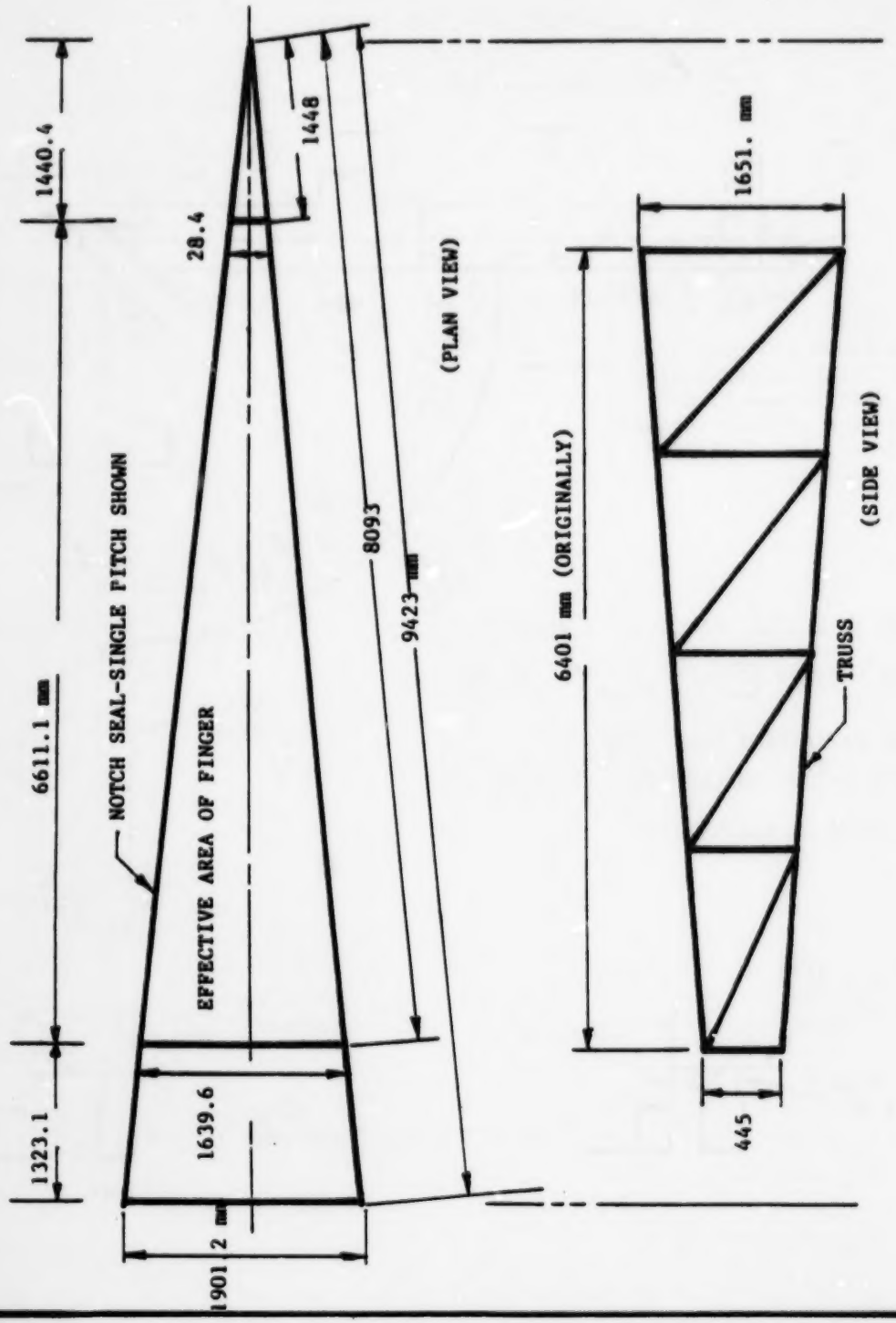
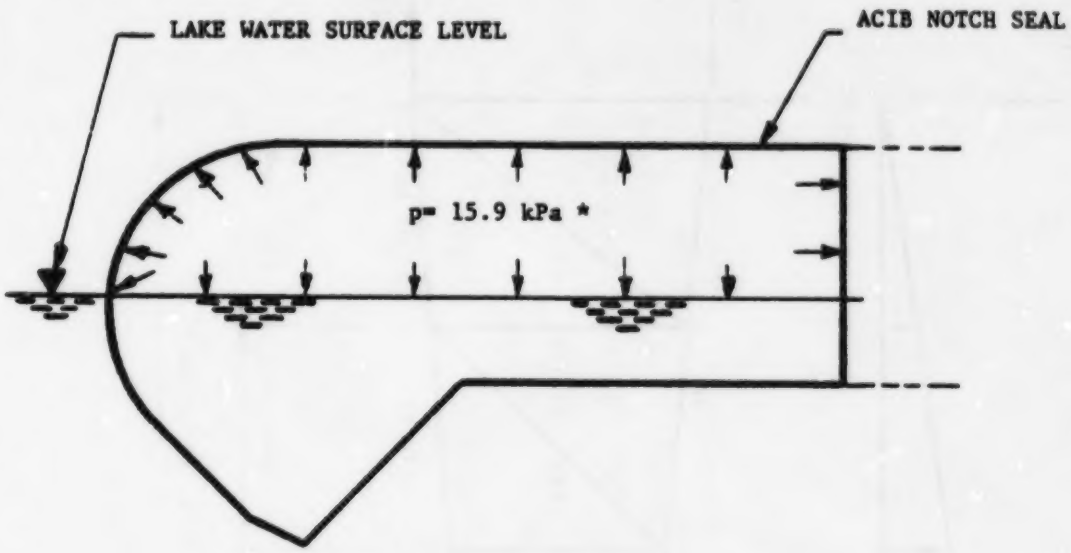


FIG. 3.1-2 GEOMETRY-SINGLE PITCH OF NOTCH SEAL FINGER AND SUPPORT TRUSS



* FAN OVERSPEED 2100 RPM, INLETS FULLY OPEN

FIG. 3.1-3 MAXIMUM POSSIBLE AIR CUSHION PRESSURE APPLIED TO NOTCH SEALS

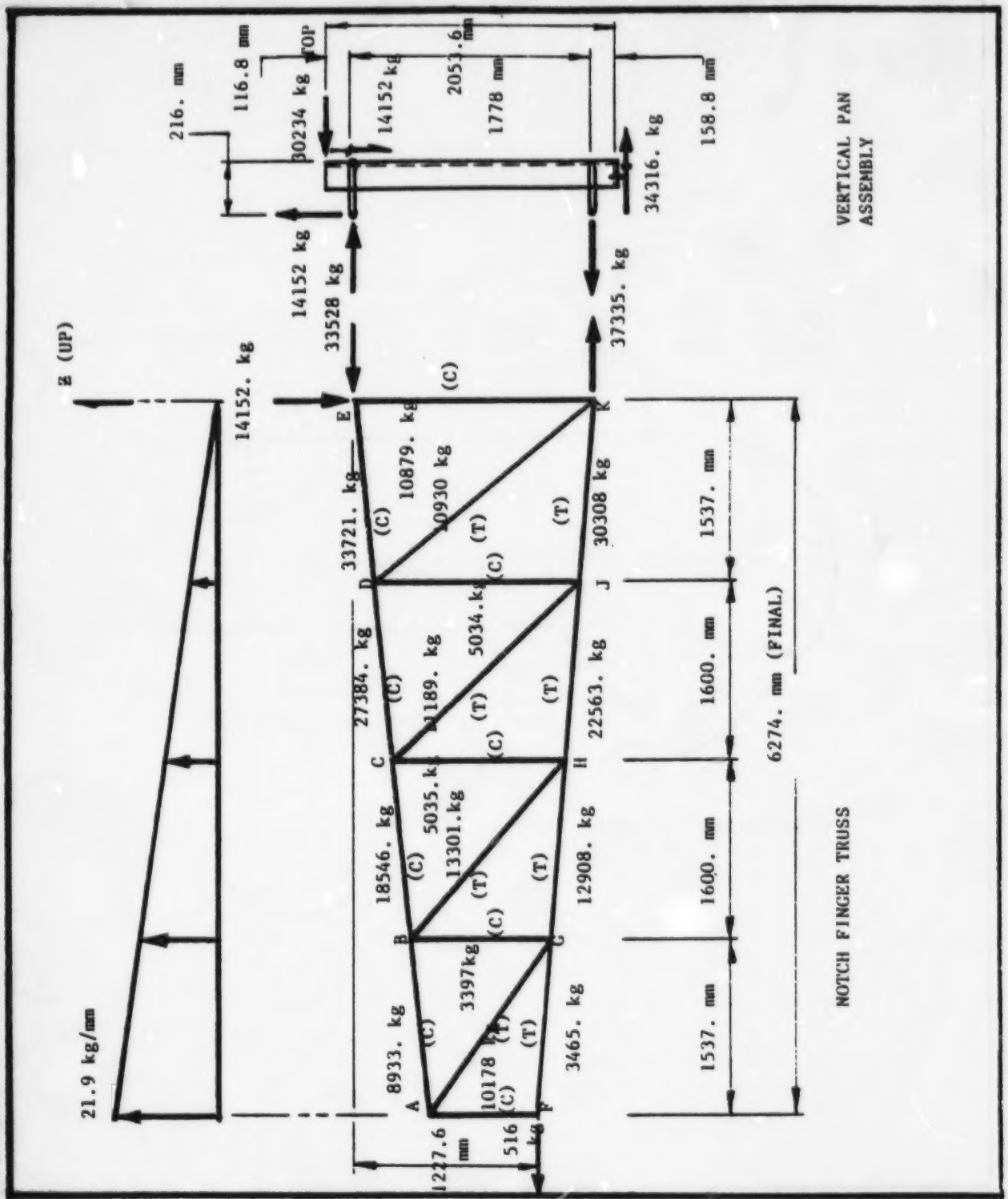


FIG. 3.1-4 INTERNAL LOADS DISTRUBUTION-NOTCH FINGER TRUSS AND VERTICAL PAN ASSEMBLY. CONDITION: MAX. POSSIBLE CUSHION PRESSURE 15.9 kPa

3.2 Seal System Analysis

The notch finger shown in Figure 3.2-1 appears at first sight to be a reasonably simple inflated structure. However, when the hard structure attachments to the carrousel and trusses are taken in conjunction with the range of water heights and wedge shaped planforms, the complete system becomes quite complex. Unless all the geometrical and physical considerations are taken into account, calculation of material loads and buckling moments could be highly misleading.

While the program could not support a full structural analysis of the notch finger, a fairly detailed analysis was made of the major buckling forces at the outboard end of the finger in the area of the last truss attachment for several conditions. A sample set of calculations is included in the Appendix. The results indicate that an upward buckling tendency exists even in the "best" condition with the ACIB on full cushion without the ice-breaker. The weight of the spray apron and chains would have to be in the order of 9 kg/cm (50 lb./in.) to remove all buckling tendencies. Alternatively, it was calculated and later confirmed by the test rig, that a similar alleviating effect could be achieved by extending the truss outboard by approximately 610 mm (2 feet).

Certainly, for the winter of 1981/82 operation which was to prove the concept rather than the performance of individual seal elements, it would not have been realistic to make the necessary provisions to remove the buckling tendency altogether. A degree of deformation is acceptable provided local stress concentrations are within safe limits.

3.3 Lift System Analysis

The final report from Phase I (Reference 1) concluded that there is adequate lift system power installed and that the fans appeared well-matched to the engines. The analysis conducted during Phase I was limited to an operating condition with fan inlet guide vanes fully open. Figures 3.3-1 through 3.3-3, reproduced from that report, show several lift system operating parameters as functions of fan RPM. Specifically, the total flow coefficient, corresponding skirt air gap and fan power required are plotted for ambient temperatures of 30°C (86°F), 0°C (32°F) and -40°C (-40°F), together with the engine power available at each temperature. This analysis has now been extended to include inlet guide vane positions up to 50° using non-dimensional fan characteristics presented in Hoverlift Report 0379 "Design of an ACV Platform Ice-breaking Attachment for Canadian Coast Guard Ship". The results are shown in Figures 3.3-4 through 3.3-18 for the same three temperatures and with inlet guide vane positions from 10° through 50°

As inlet guide vane angle is increased, both torque absorbed by the fan and the output flow are reduced. These effects are summarized in Figures 3.3-19 through 3.3-21 for temperatures of 30°C(86°F), 0°C(32°F) and -40°C(-40°F) respectively. In each case, the solid line shows the maximum engine RPM, as limited either by torque available or by the maximum governed speed of 2,100 RPM. The chain dotted line shows the

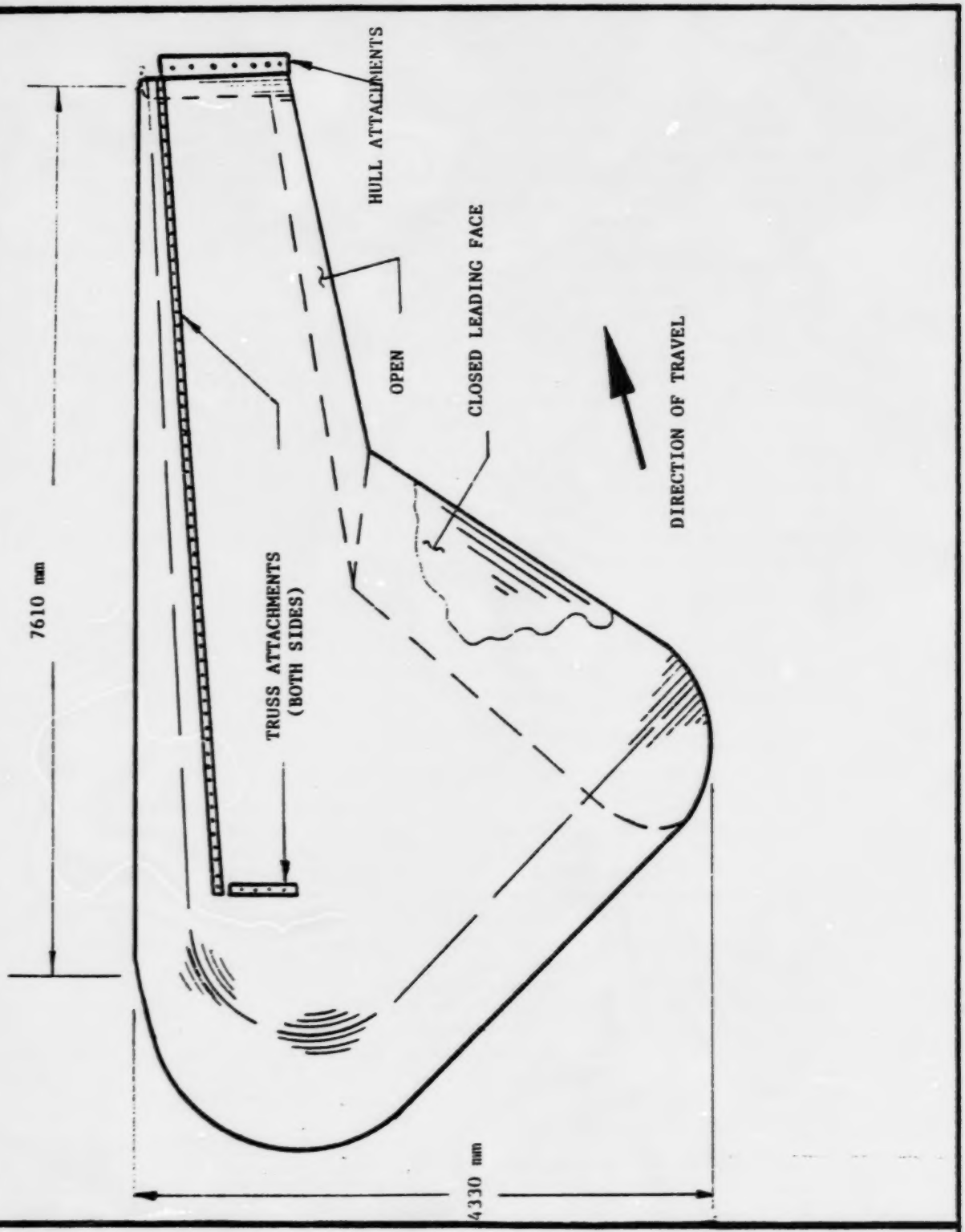


FIG. 3.2-1 TYPICAL NOTCH FINGER

maximum flow coefficient achievable, at this maximum engine RPM. As can be seen, the total flow available remains essentially constant up to the inlet guide vane position at which the governor limits RPM to 2,100. Further increase of the inlet guide vane position produces a rapid decrease in flow at constant engine speed. The large broken line shows the engine RPM at which the design flow coefficient, 0.0165, is achieved with three engines operating. The small broken line shows the corresponding power required per engine to generate the design flow coefficient. The minimum power is achieved at low vane angles and low engine RPM. It may be argued that engine life would be increased by running the same power at higher RPM, but this is considered to be unlikely. The tentative conclusion from the Phase I report, therefore, remains unchanged, i.e. the lift system should be operated with inlet guide vanes at 0° except when they are used to close off a disabled fan.

There is insufficient power to maintain the design flow coefficient with only two of the engine/fan units operating, however, sufficient flow should be available to remain fully operational. Partial closure of the inlet guide vanes will again not change this conclusion, i.e. higher engine RPM will be possible, but the total cushion flow will not be increased for this engine-out condition.

Preliminary measurements of cushion pressure at lighter operating weights during the initial trials in March of 1982 correlate well with the cushion area used in these calculations. It is assumed, therefore, that the inflated geometry of the skirt is essentially correct. At the maximum weight tested, 255 tonnes, the pressure was lower than anticipated. Maximum pressure was reached at less than 1,800 fan RPM, indicating that the ACIB had reached full cushion height. It is assumed, therefore, that the vehicle was not level in either pitch or roll for these tests.

The heave oscillation experienced, at a frequency of approximately 1 Hz, is due to the inherent instability of a deep cushion, high pressure air cushion vehicle. The frequency, approximately 1 Hz, is the natural frequency of the vehicle mass on the cushion acting as an air spring. If desired, the oscillation can be eliminated, or at least minimized, by reduction in fan RPM to a point just below full cushion. It is interesting to speculate that this phenomenon may be useful in breaking ice during unmanned operation of the ACIB.

3.4 Fuel System

The marginal nature of the capacity of the fuel tanks, led to investigation of all aspects of the fueling system. Several problem areas were discovered.

Fuel vents on the ACIB fuel tanks were inadequate. They allowed a condition, during fueling, that would enable fuel to overflow through the vent and flood the deck. Since they vented directly into the respective engine compartments (the engines having now been enclosed), this was an extremely hazardous situation. A new vent arrangement was designed which both eliminated the problem of fuel overflow and the venting of fumes into the engine compartment.

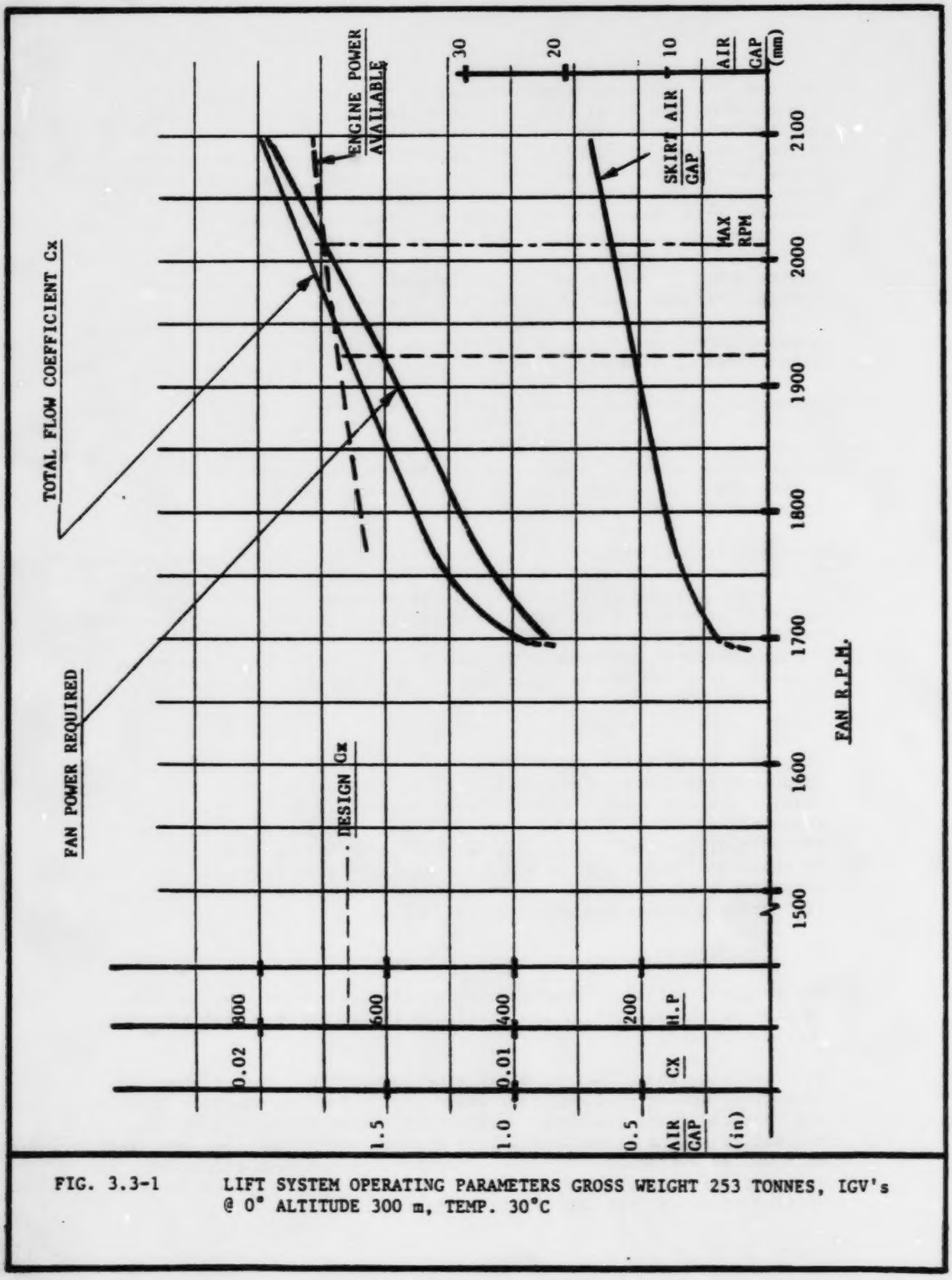


FIG. 3.3-1 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES, IGV's @ 0° ALTITUDE 300 m, TEMP. 30°C

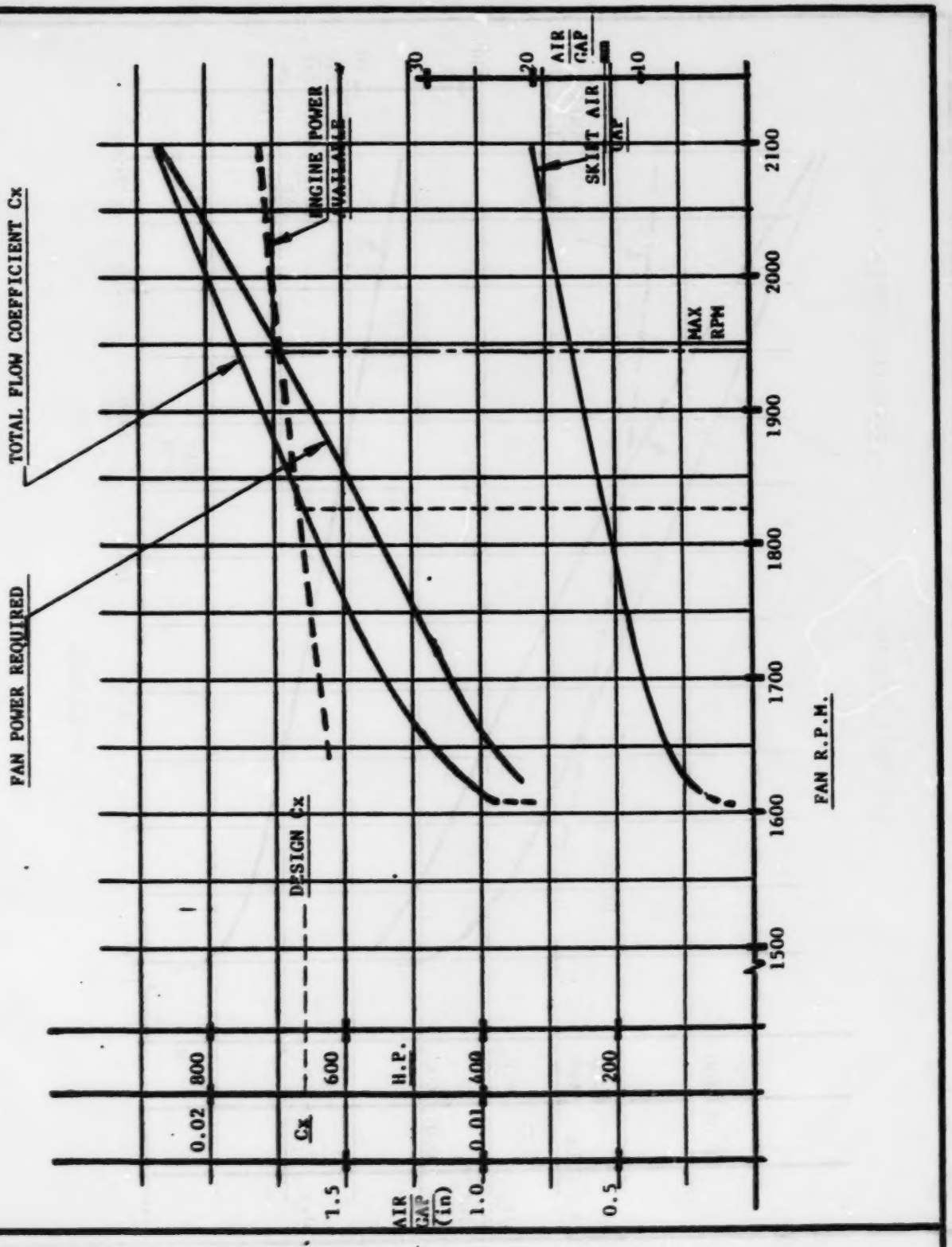


FIG. 3.3-2 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES
IGV's @ 0°, ALTITUDE 300 m, TEMP. 0°C

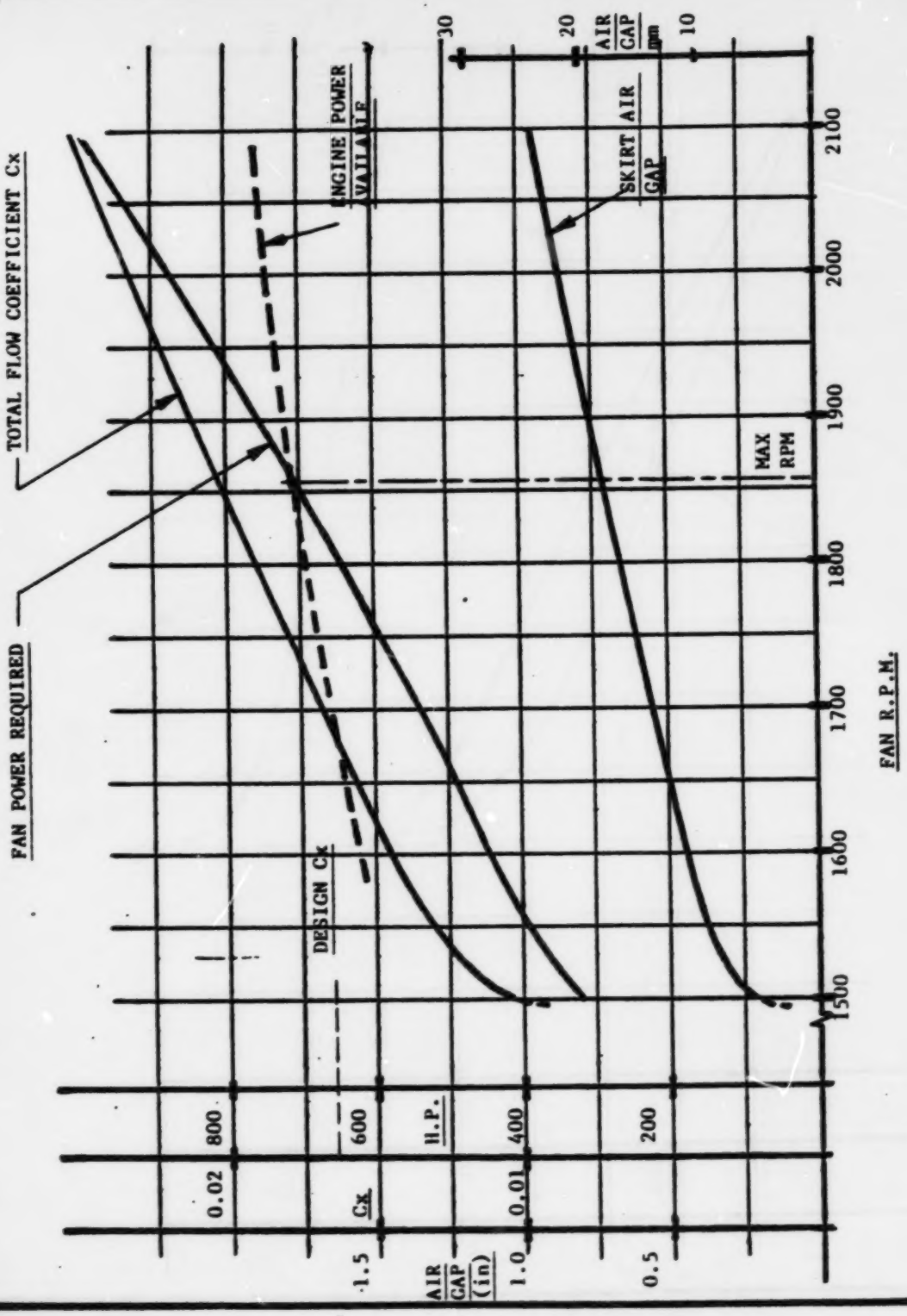


FIG. 3.3-3 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES
IGV's, @ 0° ALTITUDE 300 m, TEMP. -40°C

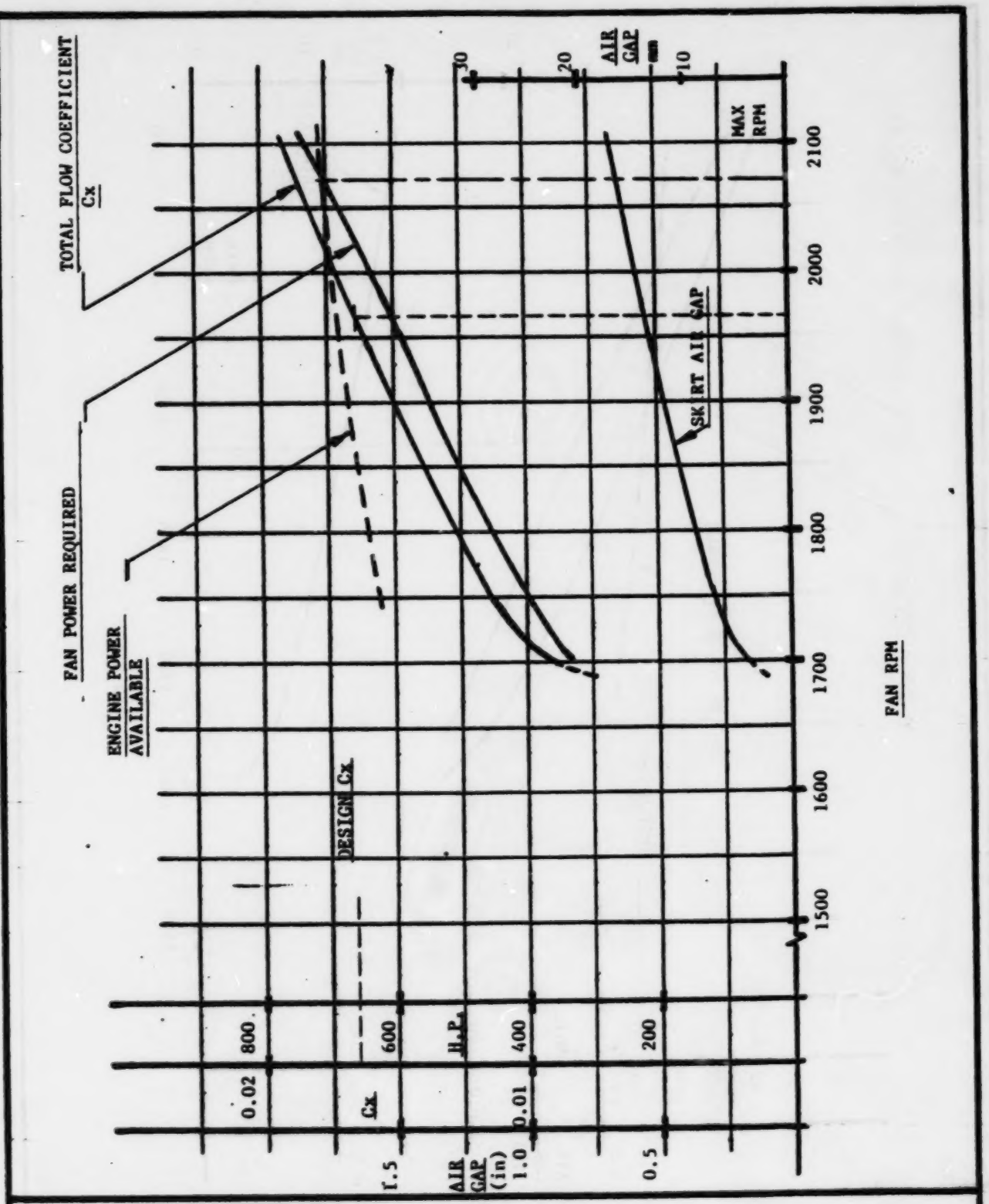


FIG. 3.3-4 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES, IGV's @ 10° ALT, 300 METERS, TEMPERATURE 30°C

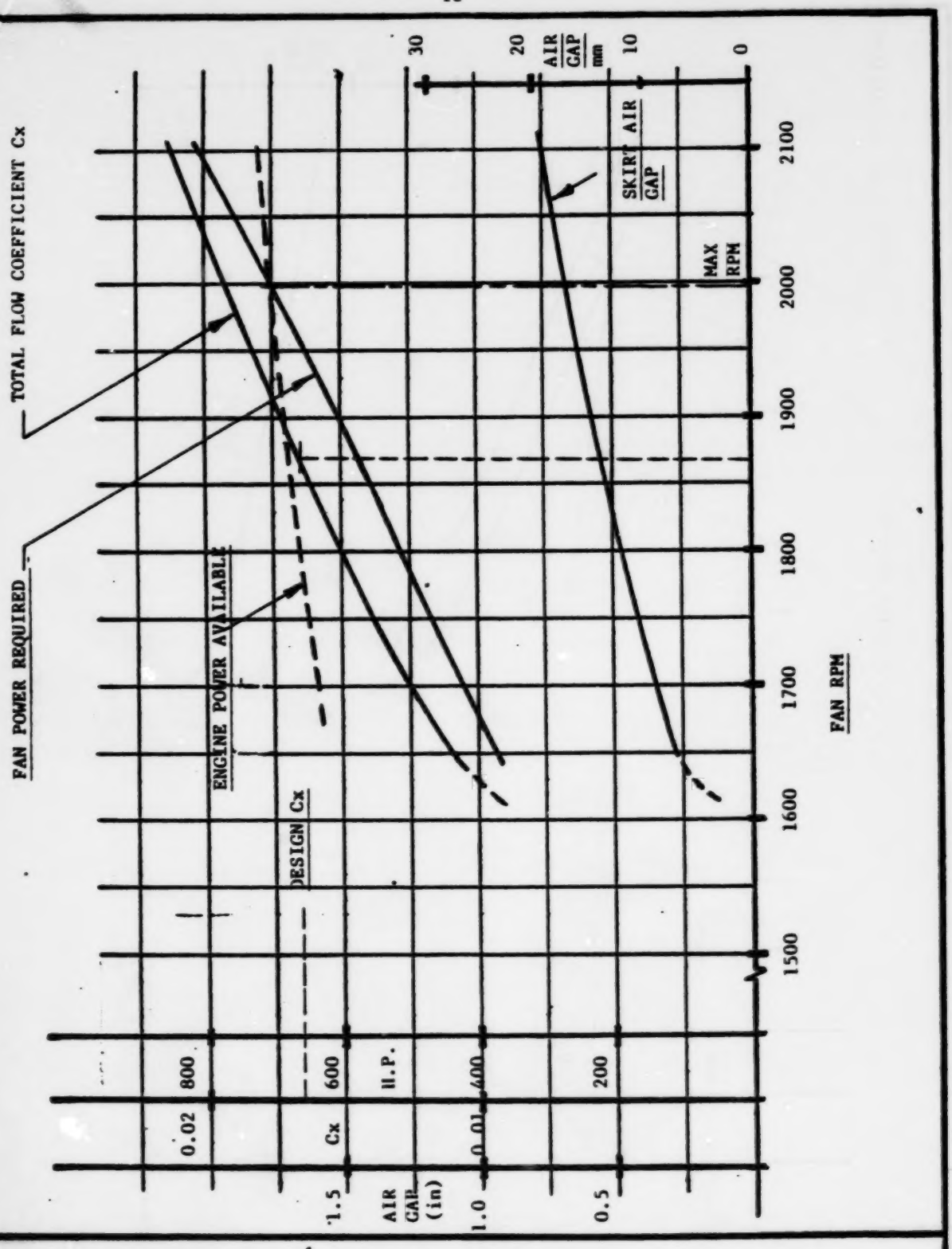


FIG. 3.3-5 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES
IGV's @ 10° ALT, 300 METERS, TEMPERATURE 0°C

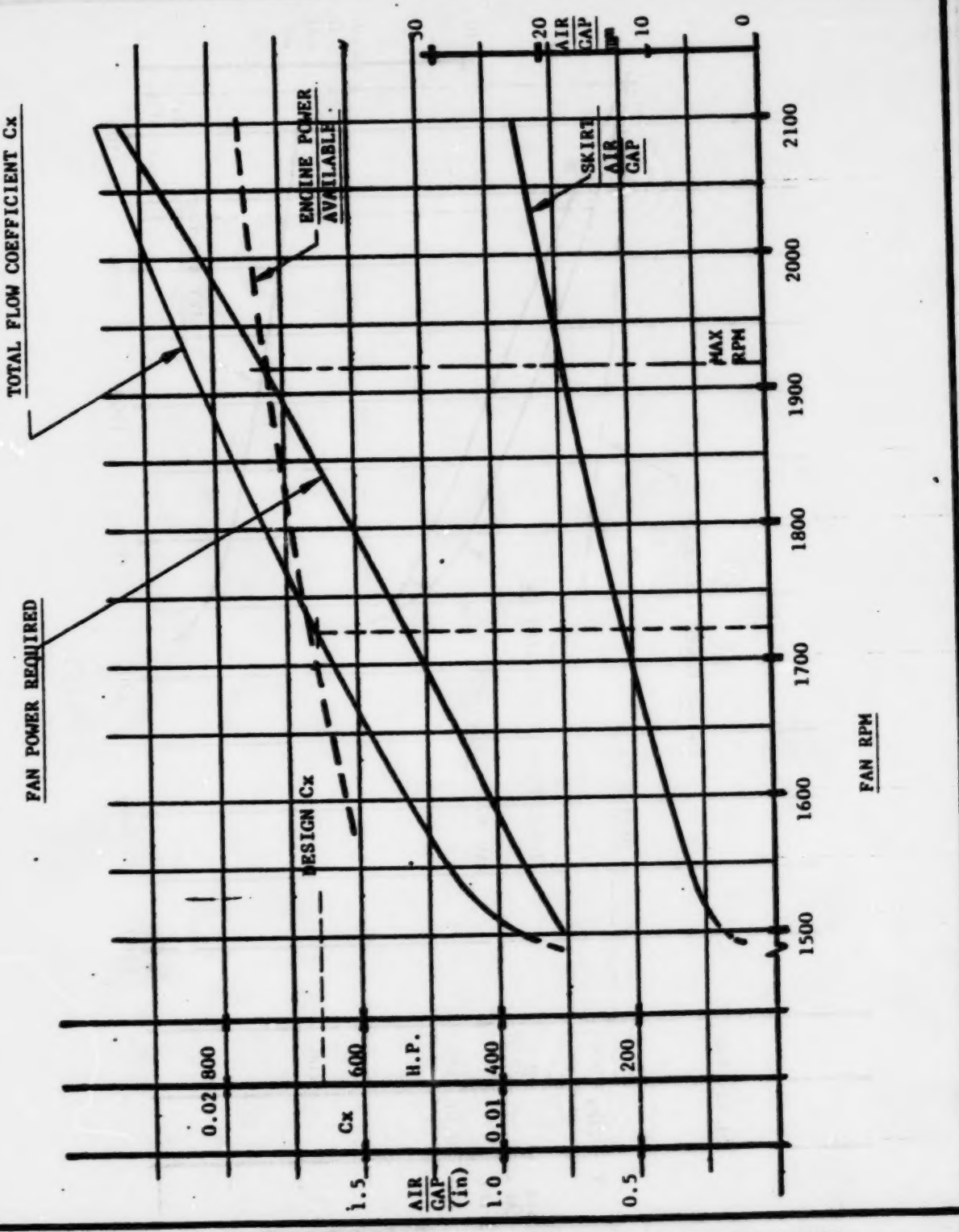


FIG. 3.3-6 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 10° ALT. 300 METERS, TEMPERATURE -40°C

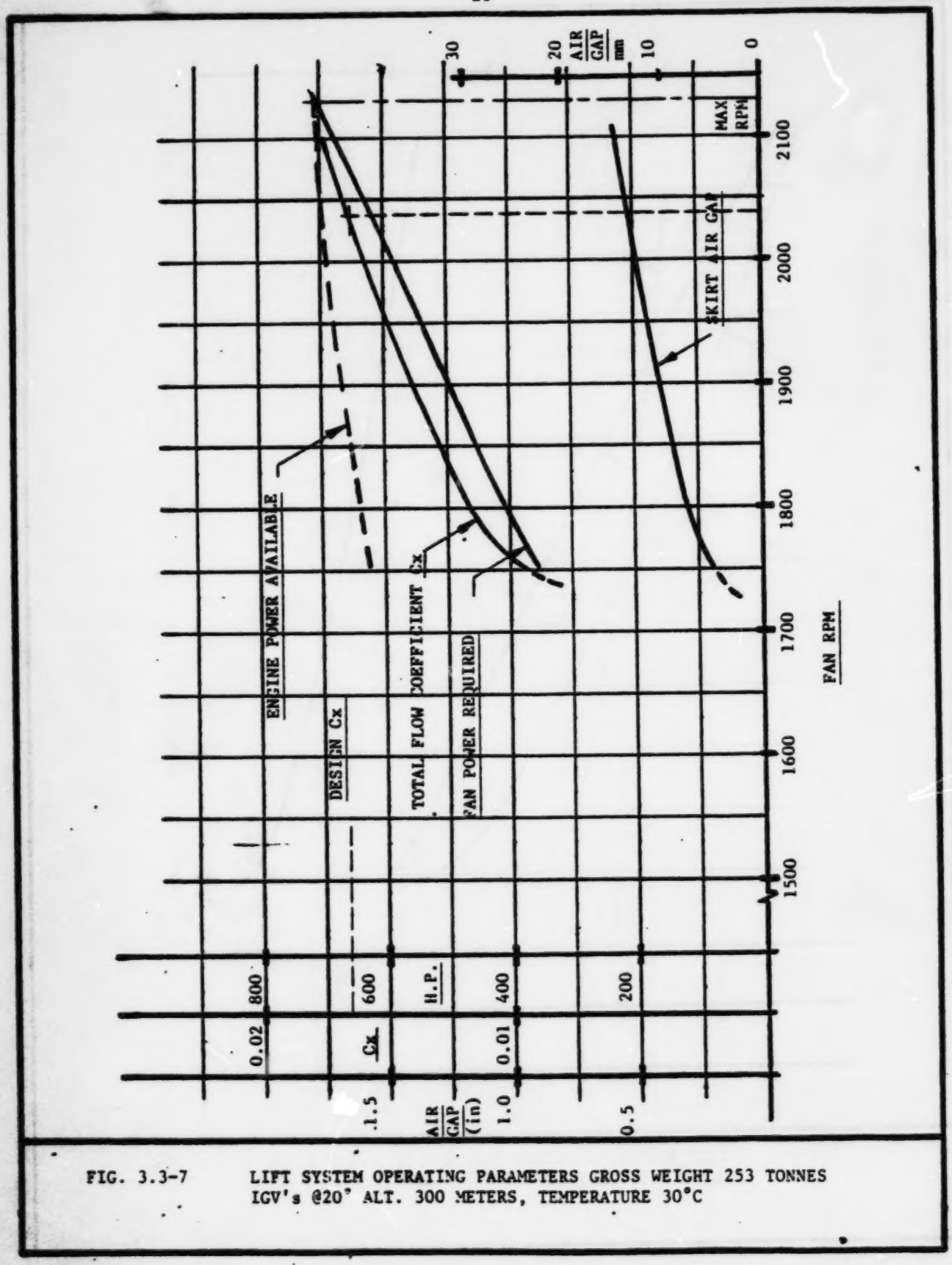


FIG. 3.3-7 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @20° ALT. 300 METERS, TEMPERATURE 30°C

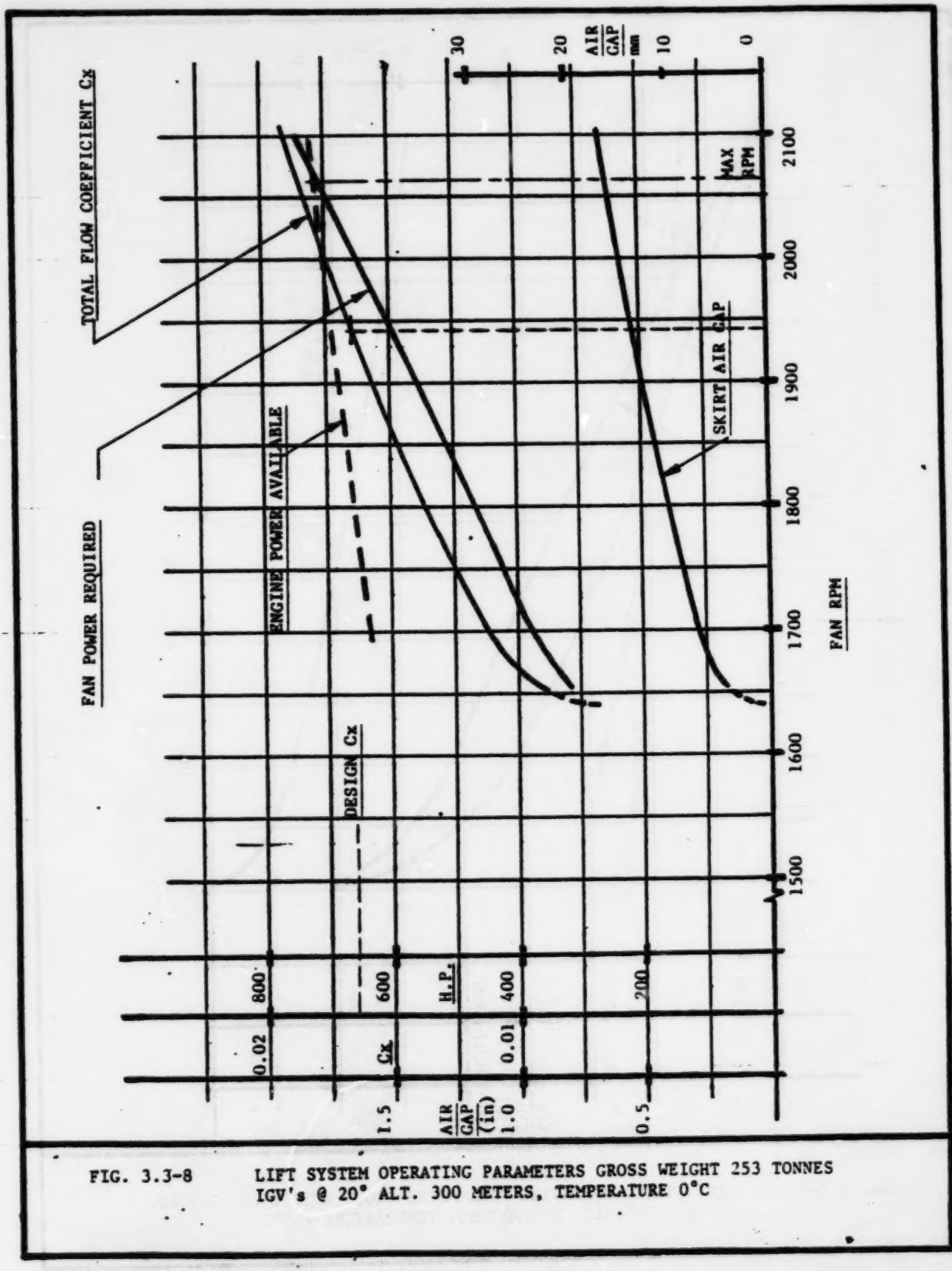


FIG. 3.3-8 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 20° ALT. 300 METERS, TEMPERATURE 0°C

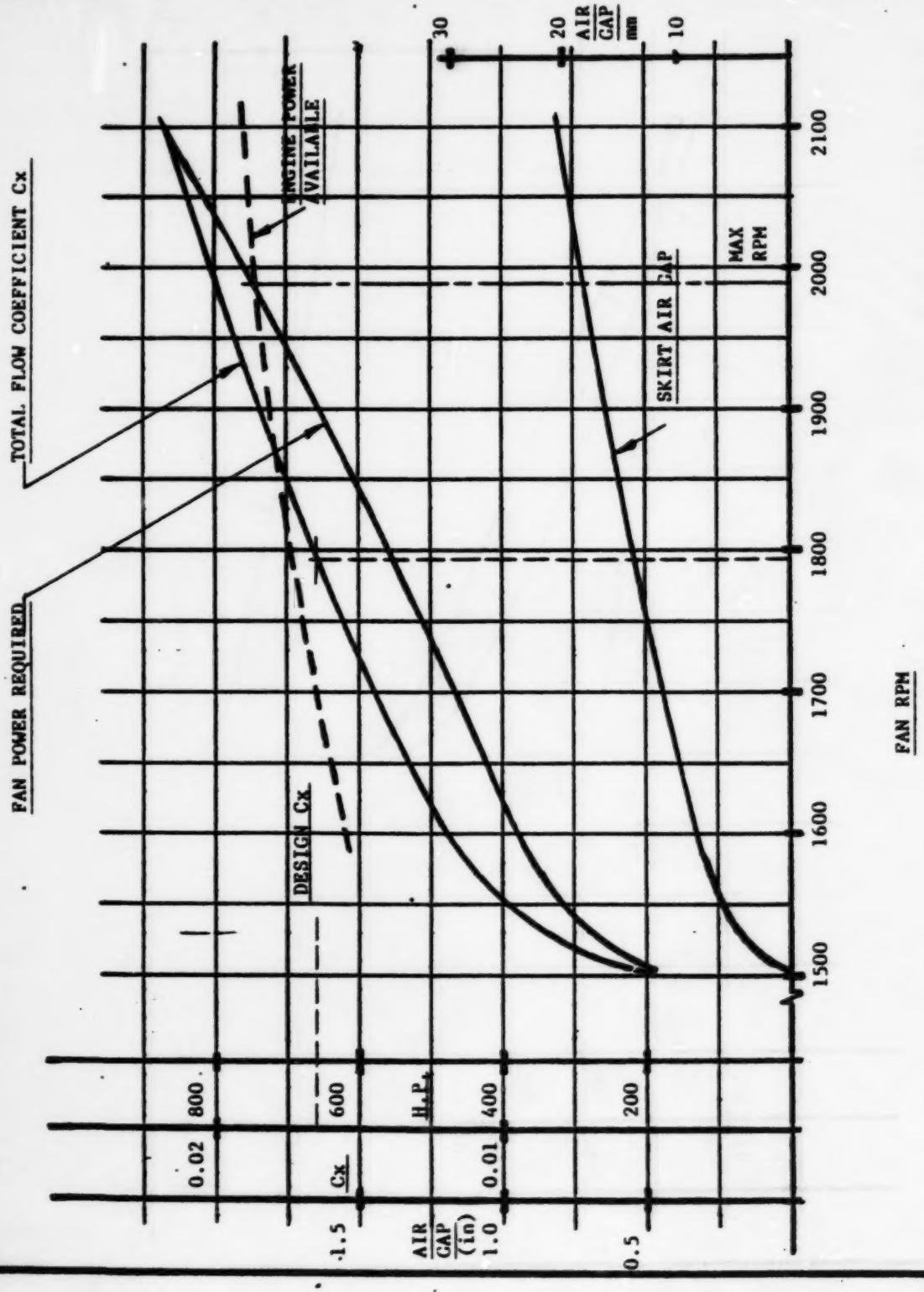


FIG. 3.3-9 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES, IGV's @ 20° ALT. 300 METERS, TEMPERATURE -40°C

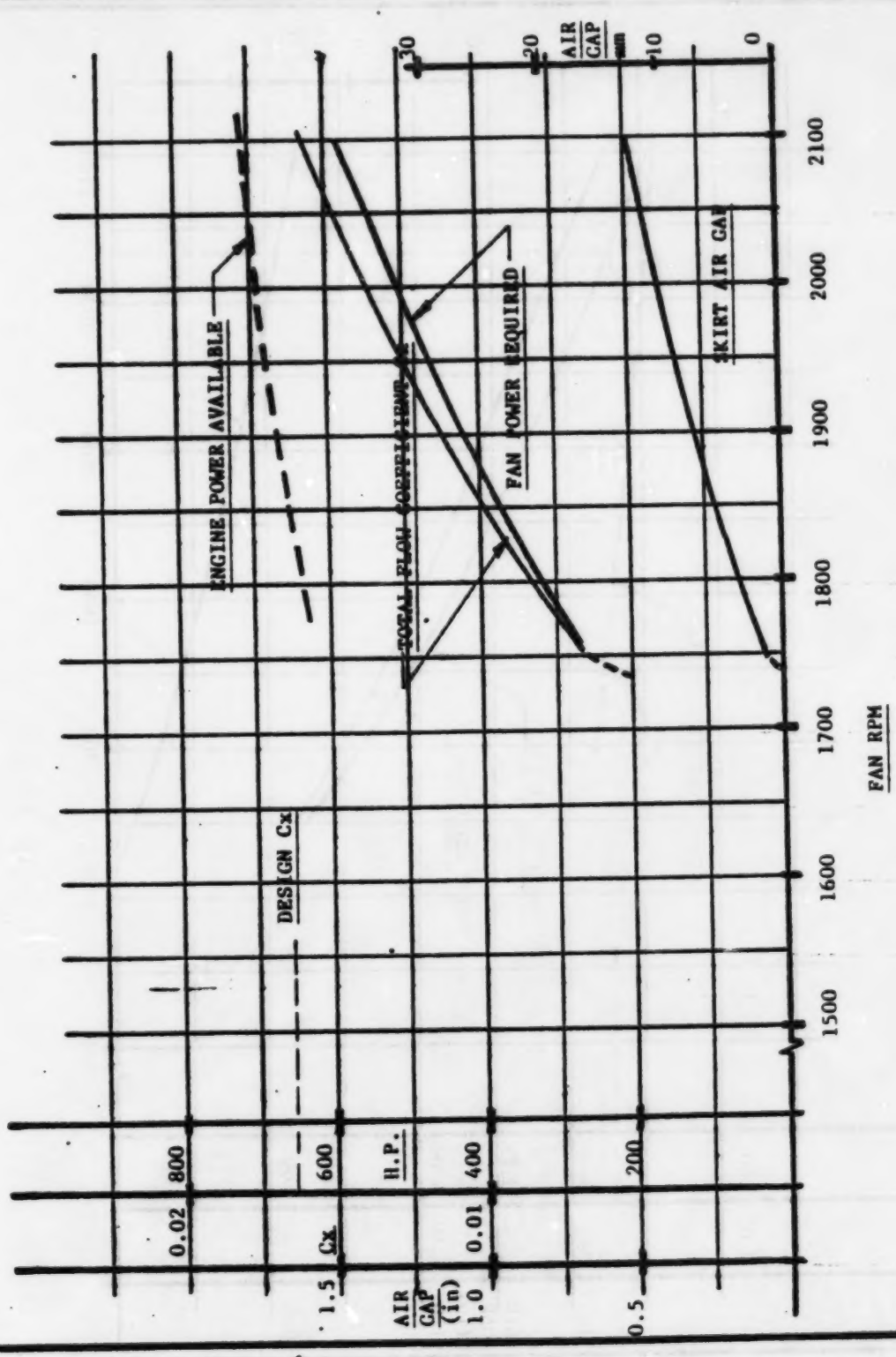


FIG. 3.3-10 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES, IGV's @ 30° ALT, 300 METERS, TEMPERATURE 30°C

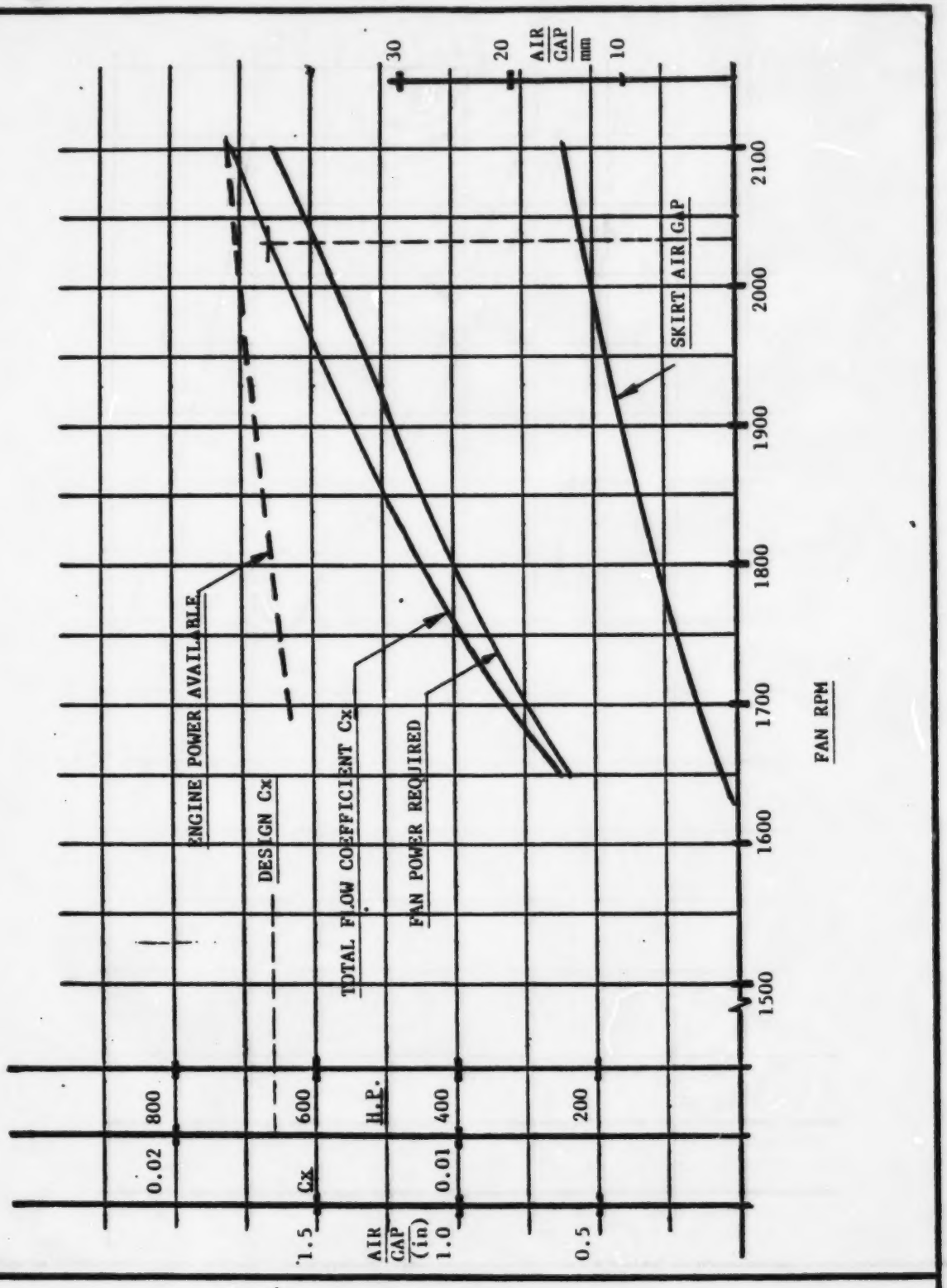


FIG. 3.3-11 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 30° ALT. 300 METERS, TEMPERATURE 0°C

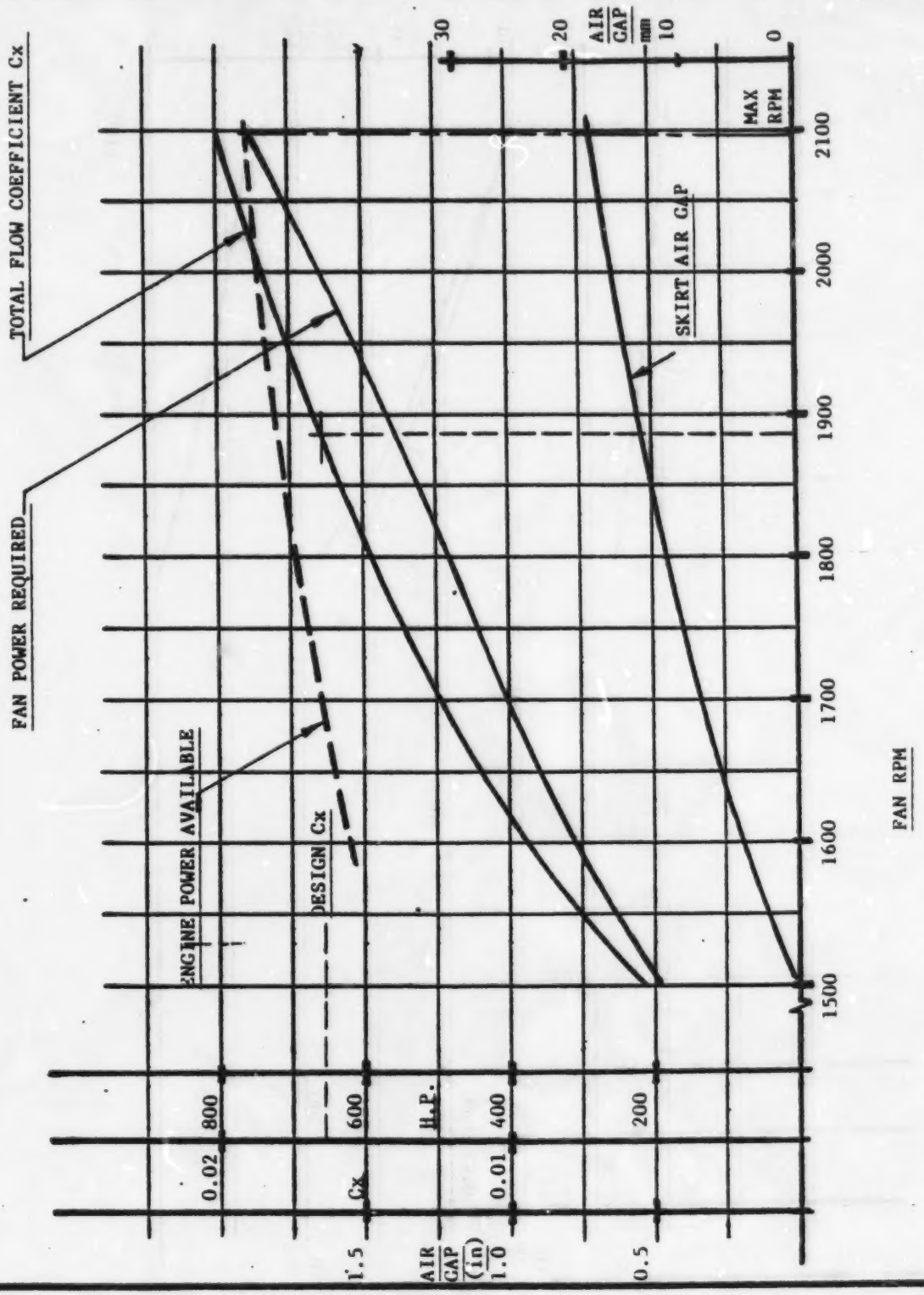


FIG. 3.3-12 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 30° ALT. 300 METERS, TEMPERATURE -40°C

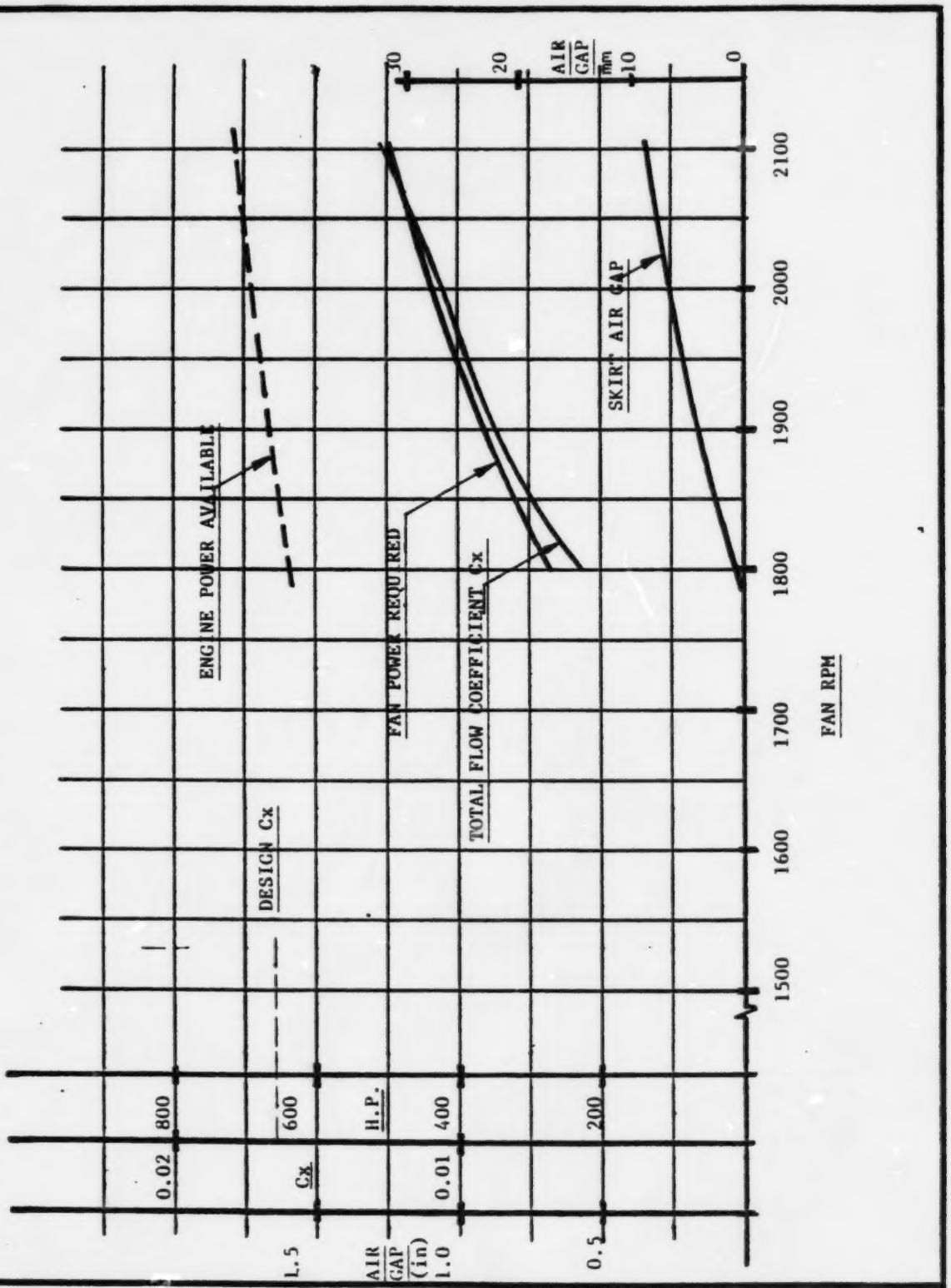


FIG. 3.3-13 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 40° ALT. 300 METERS, TEMPERATURE 30°C

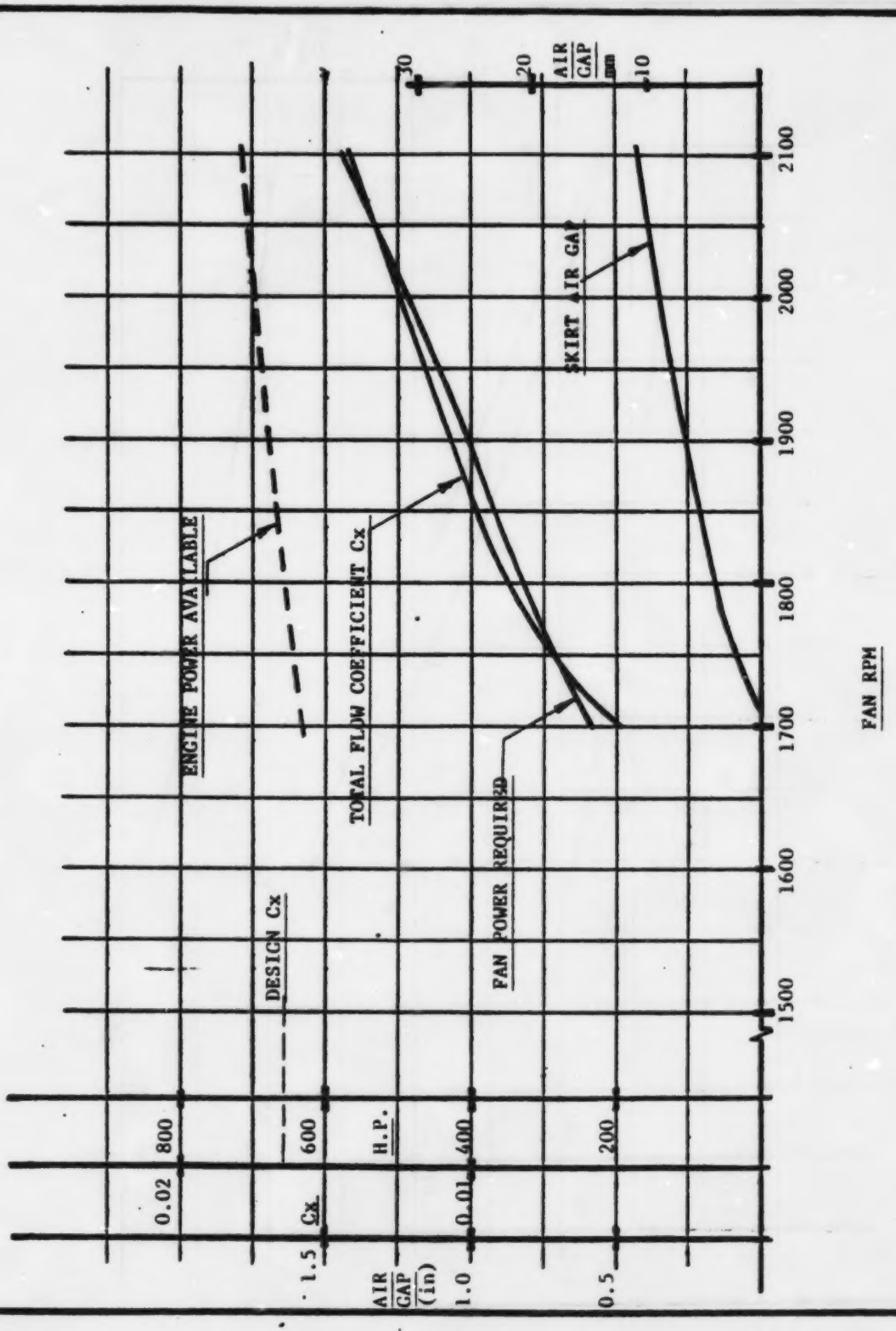


FIG. 3.3-14 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 40° ALT. 300 METERS, TEMPERATURE 0°C

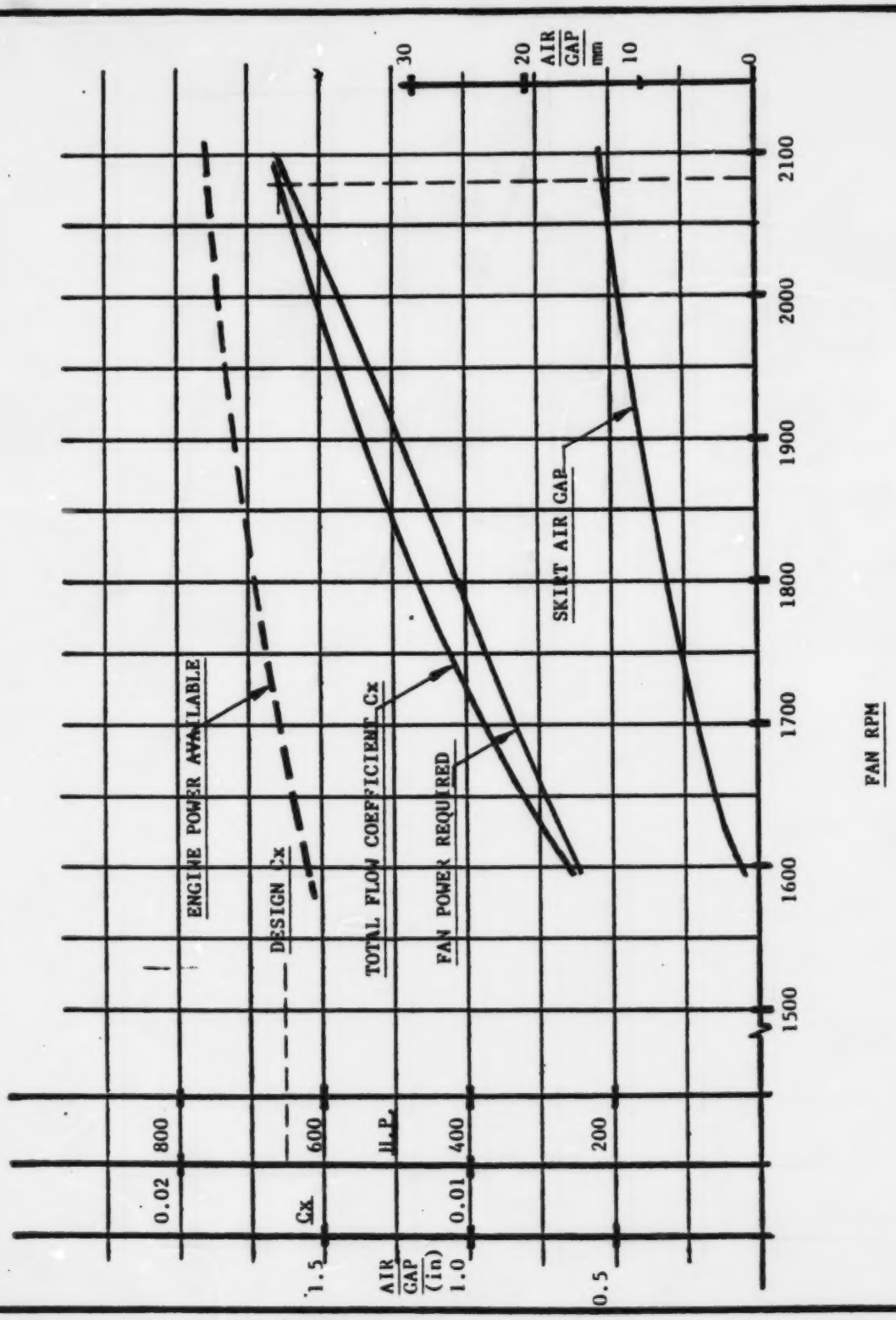


FIG. 3.3-15 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 40° ALT. 300 METERS, TEMPERATURE -40°C

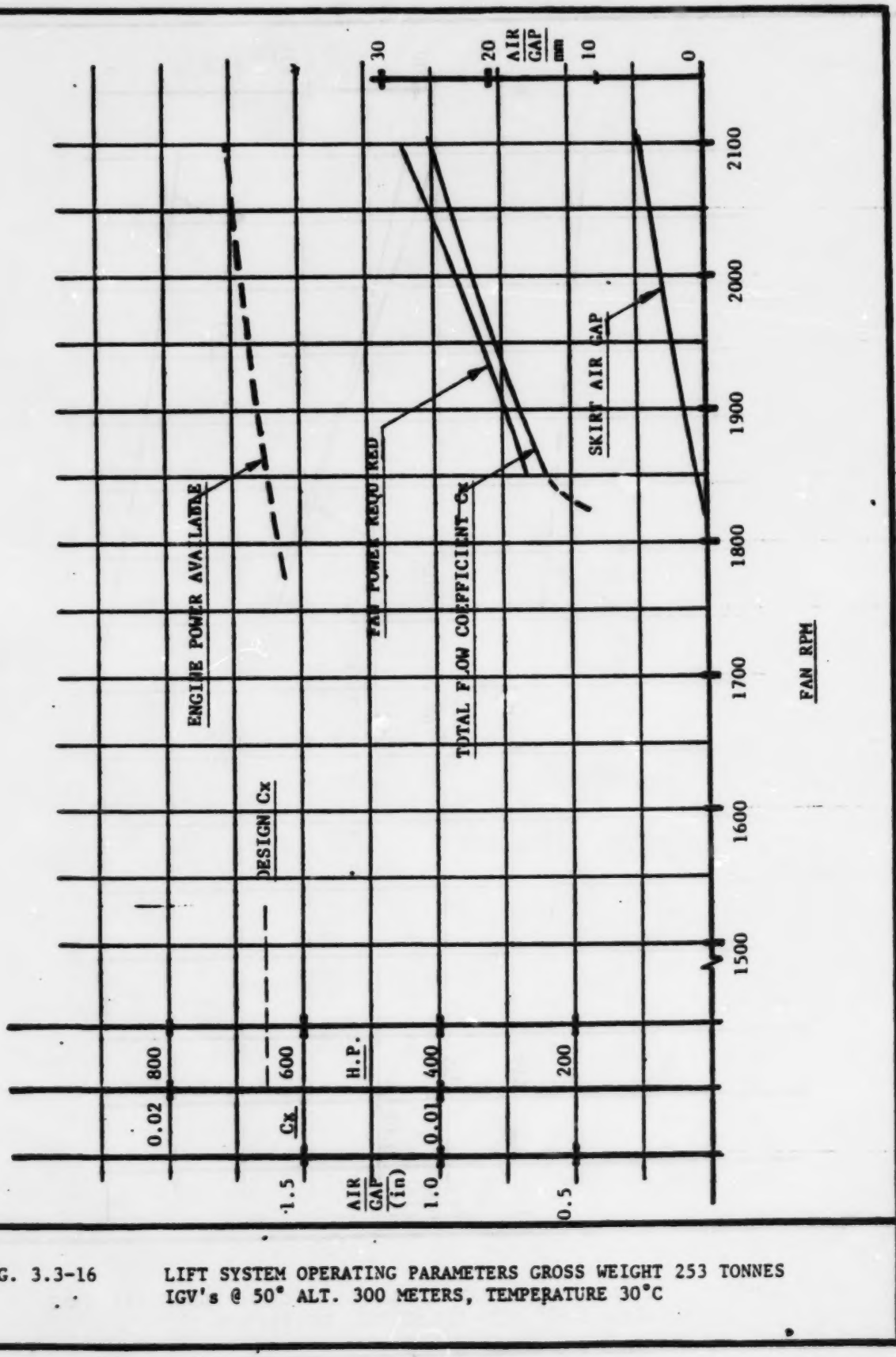


FIG. 3.3-16 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 50° ALT. 300 METERS, TEMPERATURE 30°C

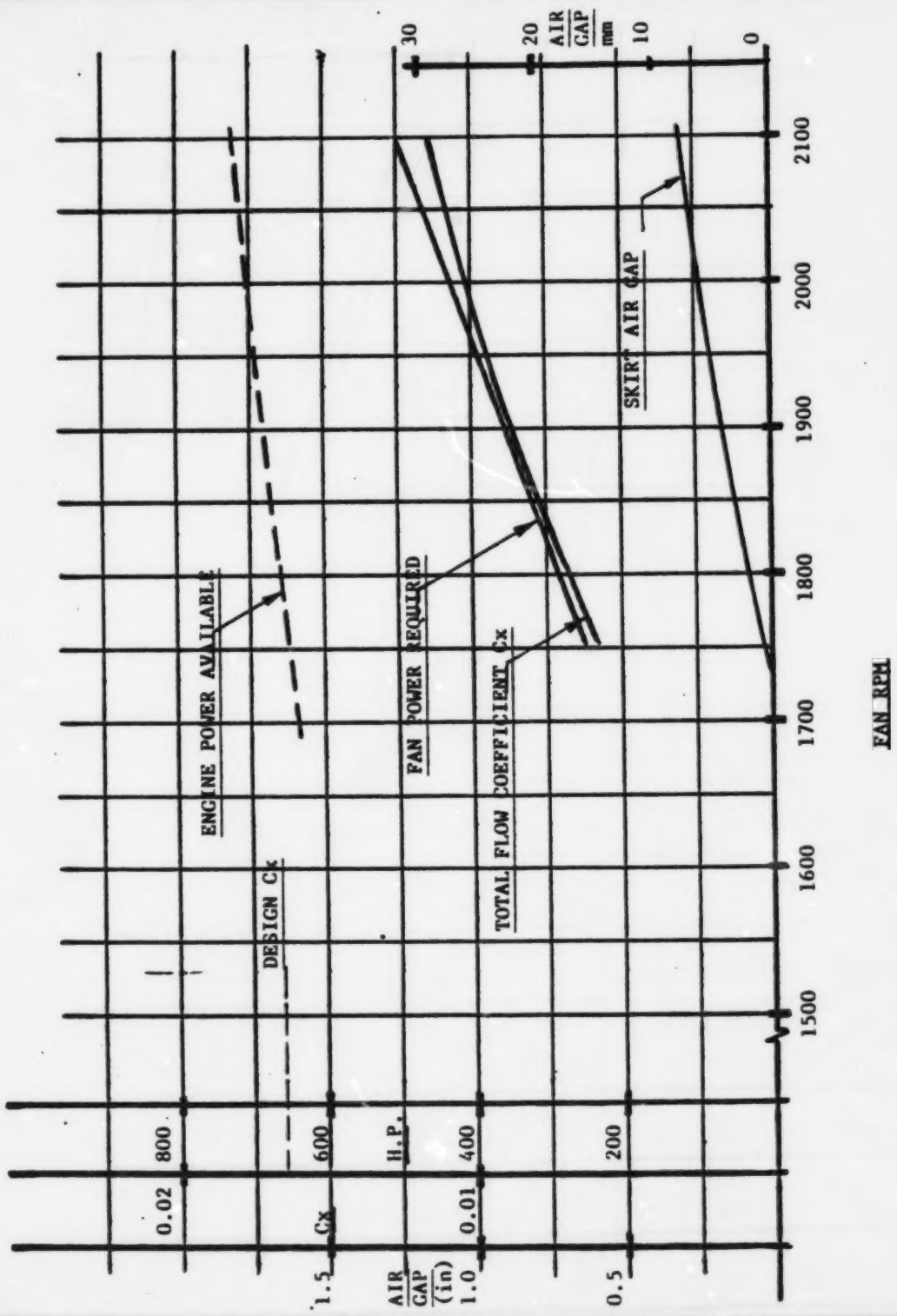


FIG. 3.3-17 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 50° ALT. 300 METERS, TEMPERATURE 0°C

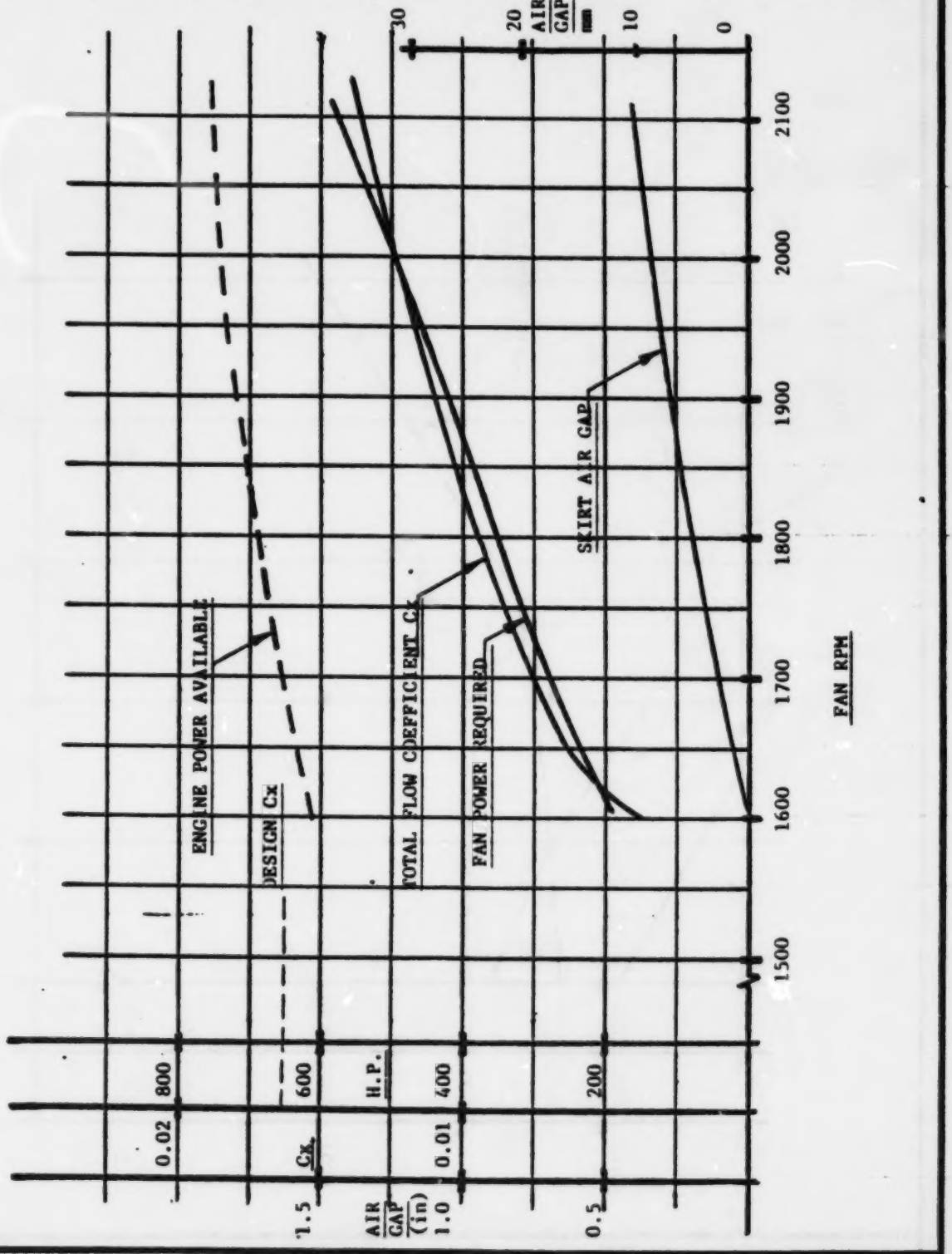


FIG. 3.3-18 LIFT SYSTEM OPERATING PARAMETERS GROSS WEIGHT 253 TONNES IGV's @ 50° ALT. 300 METERS, TEMPERATURE -40°C

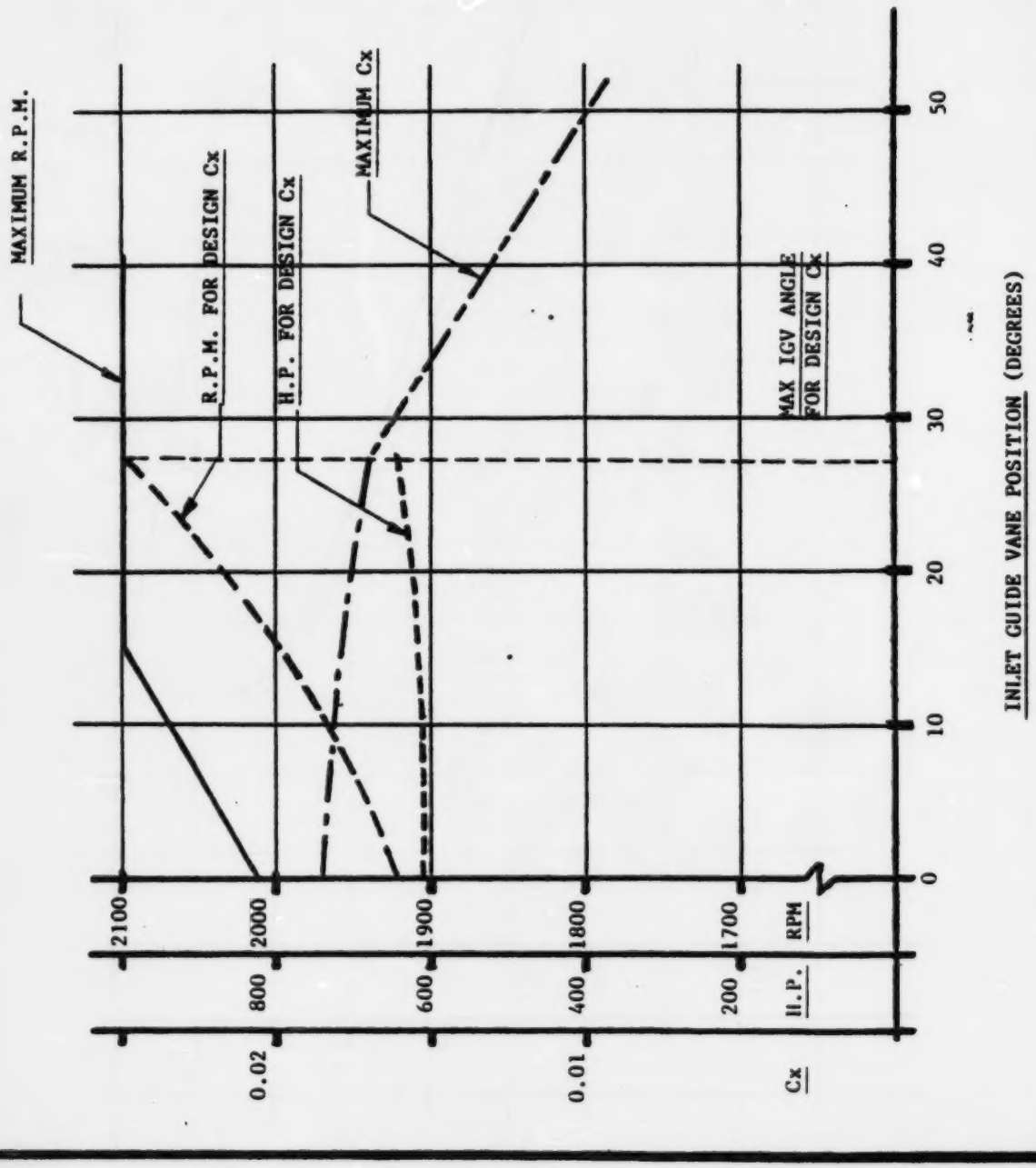


FIG. 3.3-19 EFFECTS OF INLET GUIDE VANE POSITION GROSS WEIGHT 253 TONNES TEMPERATURE 30°C

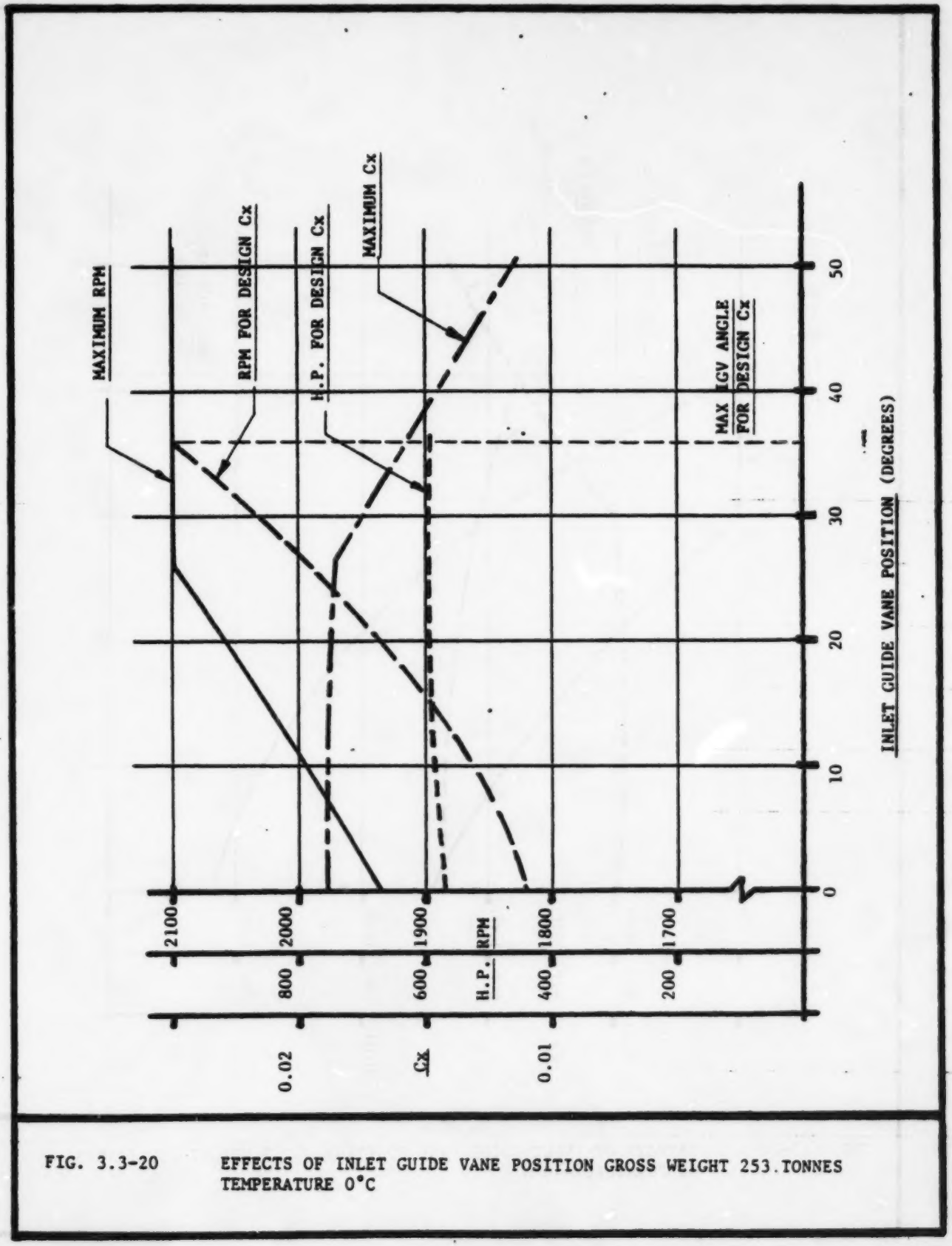


FIG. 3.3-20 EFFECTS OF INLET GUIDE VANE POSITION GROSS WEIGHT 253.TONNES TEMPERATURE 0°C

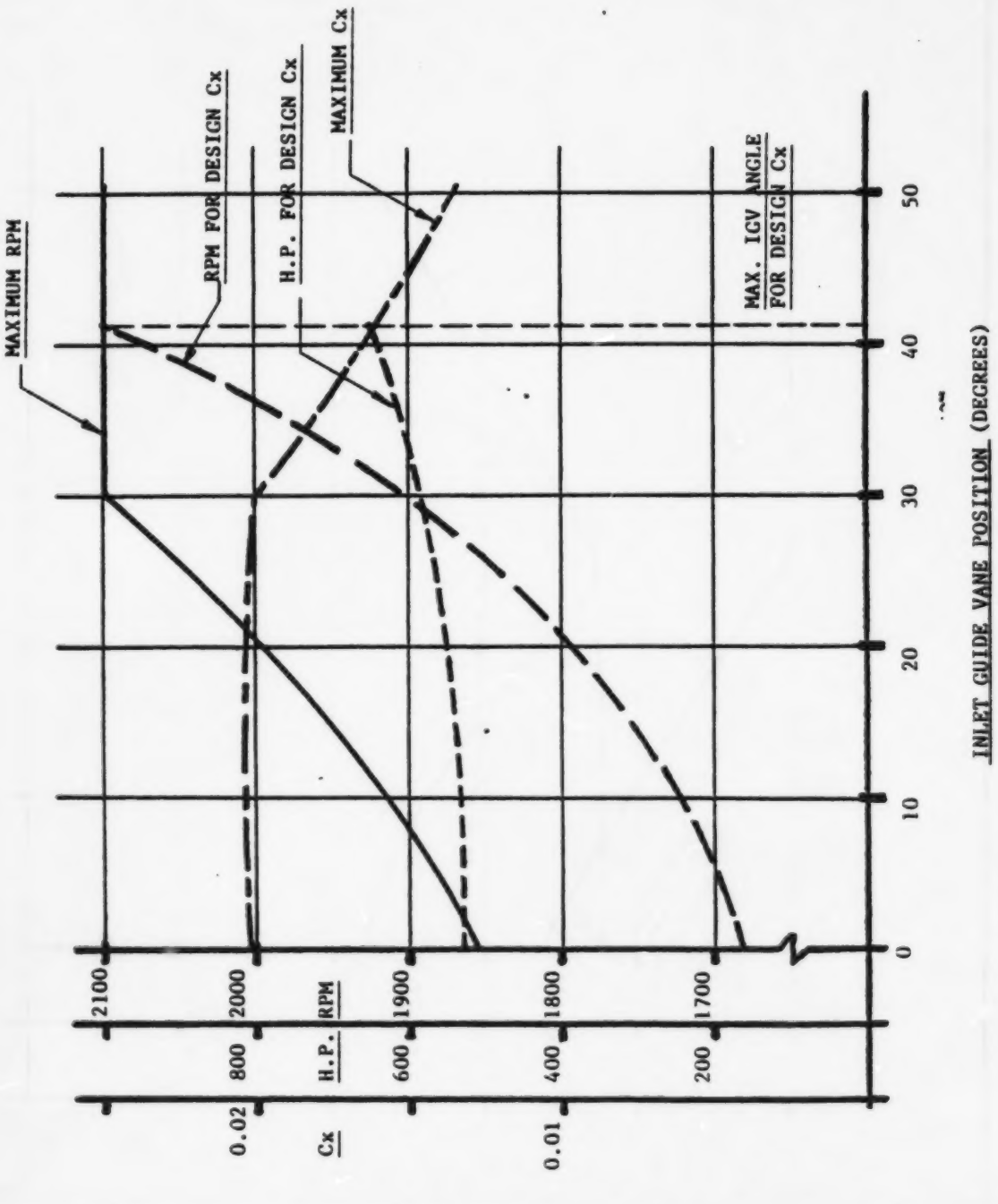


FIG. 3.3-21 EFFECTS OF INLET GUIDE VANE POSITION GROSS WEIGHT 253 TONNES TEMPERATURE -40°C

All of the original fuel lines, as well as the supply line from the Alexander Henry, were of insufficient size to prevent the back pressure rise at the fill nozzle from tripping the nozzle cut-out. This precluded attaining the full flow desired and prevented filling the ACIB fuel tanks as quickly as required. The first and second tanks could be filled with reasonable success, however, problems of premature trip-off would occur with the filling of tank No. 3. Time to fully redesign the fuel fill system was not available.

None of the fuel lines were electrically bonded either to each other or to the main body of the ACIB. While it may not be normal practice to electrically bond fuel lines on marine craft, this is an experimental craft and all possible safety precautions should be taken. Also, due to the shortcomings of the vents, a possibility exists for fuel spillage and accompanying volatile vapour. A bonding installation was detailed and included as a portion of the craft redesign by BACT.

3.5 Winch Controls

The winch electrical controls, as detailed by BACT, were designed to operate the winches as requested by the CCG. No problems were foreseen in the controls. However, there was some concern regarding one winch operating condition.

Under one of the operating modes required, it would be possible to draw all the hydraulic fluid from one reservoir, and return it to another. Since there was no connection between the two reservoirs, this could deplete all of the fluid in one system causing it to fail. Some corrective action was necessary to prevent this occuring. An equalizing line between the two tanks was recommended by BACT, using the existing plumbing.

3.6 Electrical Systems

Several important changes were made to the electrical system design. Most important of these changes was the interconnection, added at CCG request, between the "Extinguish" pushbutton at each panel and the "Emergency Stop" function of the corresponding engine. This insures that the engine will be stopped if a fire is detected and the attempt is made to extinguish it. As well as this, an "Extinguish" pushbutton was added at each engine enclosure to prevent the "Emergency Stop" pushbutton from also activating the fire bottles.

Circuitry was altered to allow monitoring of engine gauges and warning lights at all three locations continuously. Several fused circuits were upgraded to larger fuses to prevent operational failures.

Navigation lights were not in accordance with Coast Guard regulations. A flashing amber beacon and the capability to power a set of Not Under Command lights were added. Previously the navigation lights had been designed as plug in units, they were redesigned to be wired directly.

4. RESULTS

4.1 Rig Tests

The general behaviour, structural support and air supply requirements for the model seal had already been determined during the first phase of the program. It was during the second phase that it was discovered that the Alexander Henry bow was not compatible with the external truss arrangement. The rig was, therefore, modified for the internal truss arrangement and testing continued with the development of the stem seal and procedure for inserting the ice-breaker bow. The truck tire provided the means of raising and lowering the hull module to represent the ACIB coming on and off cushion. The behavior of the two notch fingers next to the relatively smooth surface of the 1/10th scale model hull gave no cause for concern. Provided the cover plates on the Alexander Henry anchor pockets were reasonably flush and smooth, it was considered that the operation should function similarly at full scale.

The rig demonstrated the importance of inserting the bow into the notch seal, with the latter off-cushion and the notch seals spread open. At the same time, the danger of bow interference with the inboard trusses adjacent to the carrousel with the ACIB off-cushion and the pushing posts out of contact with the hull was underlined.

The rig was also used to visualize the effects of reduced/shortened notch finger truss support and to aid in the analysis of inflation loads, material stresses and seal/pushing post contact areas on the Alexander Henry (see Figure 4.1-1).

4.2 Hull Modification & Installation

Modifications and additions to the carrousel were found necessary to bring the existing structures up to the required strength. Figure 3.1-1 illustrates some of these changes.

The lack of sufficient cushion air supply to the notch fingers in the hullborne mode was corrected by the addition of an "L" shaped rectangular cross-section duct running through the upper section of the port buoyancy tank. The 0.4m² (4.2 ft.²) duct was arranged so that air from the port fan exit was tapped and partially by-passed directly to the upper port side wall of the carrousel where it could initiate the inflation of all the notch fingers via feed holes located in the main carrousel wall.

The welding operations to make the required changes on the carrousel were extensive and in spite of its basically heavy construction, considerable distortion took place and great difficulty was experienced in re-attaching the unit to the ACIB. All but one important bolted connection was made, however, and this had to be welded. Air sealing load carrying plates were welded top and bottom between the carrousel and the adjacent buoyancy tanks at completion.

Installation of the truss support structure on the carrousel met with an interference and tolerance problem at the fitting on the main load carrying pins. A fit was obtained by the removal of a welded strap, required only on the original installation.

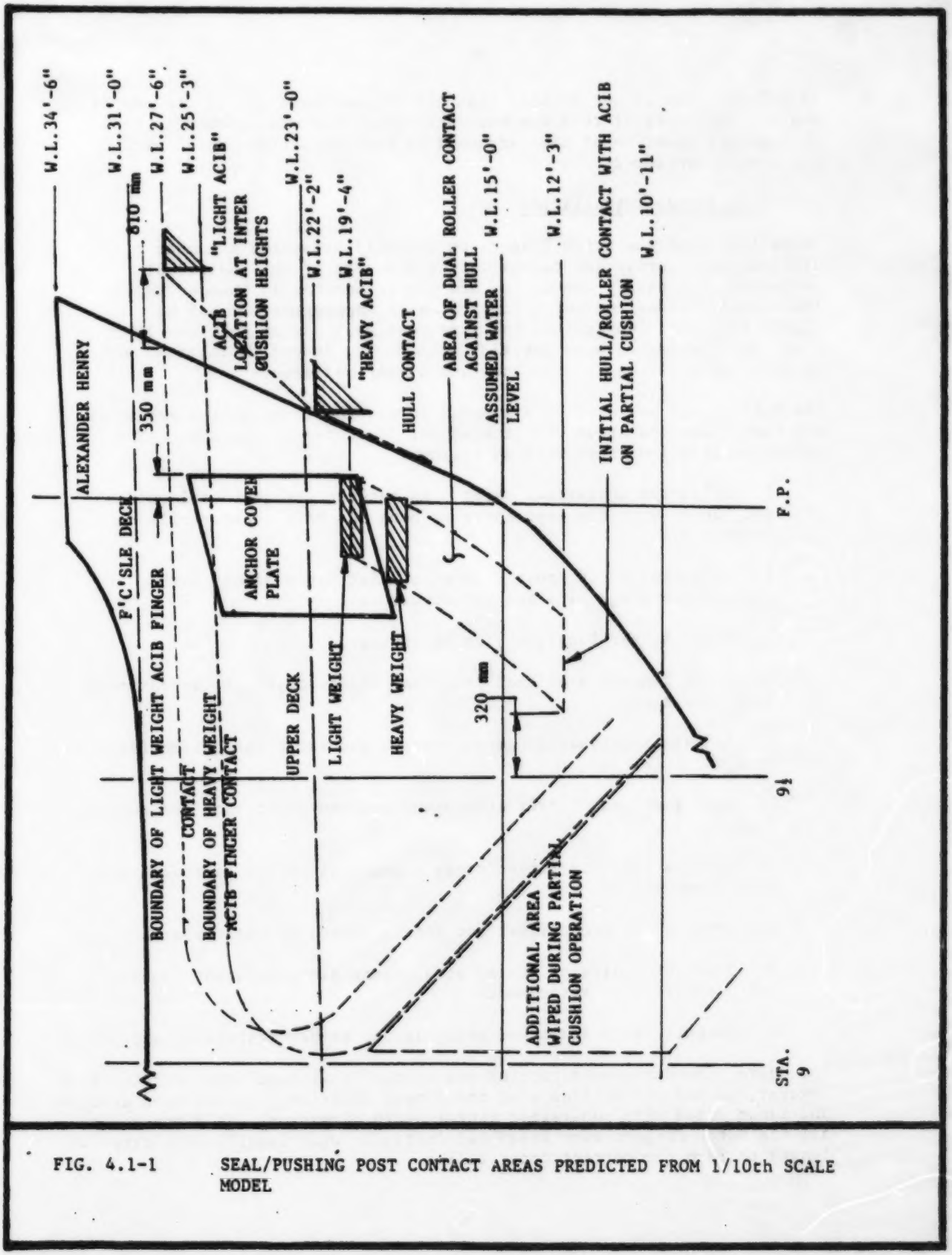


FIG. 4.1-1 SEAL/PUSHING POST CONTACT AREAS PREDICTED FROM 1/10th SCALE MODEL

At a later date it was noticed that the trusses were not at the proper angle. The cause of this was not determined, but was assumed to be due to improper mounting of the carrousel or the distortions which were previously mentioned.

4.3 Seal System Installation

Installation of the notch fingers on the ACIB presented a number of difficulties, partly due to the weight and size of the individual components and partly due to the mid-winter weather in Thunder Bay. Individual trusses and notch fingers weigh approximately 635 kg (1,400 lbs.) and 204 kg (450 lbs.) respectively and at 8530 mm (26 ft.) long, the components were unwieldy both during indoor fabrication and outdoor installation in deep snow and a confined area.

The ACIB itself was used as a support during the installation procedure and the entire operation was, therefore, conducted in the open. The major installation steps were as follows:

1. Slide the individual skirt pans between the carrousel guides and locate over the load carrying pins and bolt temporarily to carrousel.

2. Permanently fit trusses to each skirt pan assembly with appropriate hinge pins and thrust washers.

3. Erect finger location jigs on trusses.

4. Slide fingers over each truss and location jigs to approximate final position.

5. Remove individual fingers, trusses and skirt pan assemblies from the ACIB.

6. Make good each finger attachment between skirt pans and support frames.

7. Replace complete finger/truss assemblies on the carrousel and bolt permanently.

8. Stretch out each finger and locate centrally over location jigs.

9. Make good pairs of finger attachments along adjacent trusses and outboard hull attachments.

10. Install stern seals and spray aprons as per installation drawings.

The above procedures were carried out initially without major difficulties, however, it was not noticed that the finger location jigs had been designed and constructed with undersized finger width dimension. As a consequence, all the notch fingers were assembled initially with insufficient material length to form the correct upper radius.

4.3.1 Notch Finger Repairs

The notch fingers suffered a number of splits and tears as a result of the initial trials in Calgary and in shipping to Thunder Bay. This damage was made good before installation on the ACIB. Figure 4.3-1 shows a typical finger repair. In two cases, sharp projections on the notch sidewalls caused the damage. These were burned back and ground smooth.

In addition to the repairs, the fingers were also modified in order to fit the new trusses. This required the removal of the five 127 mm (5") diameter hoses and fittings from each finger and the internally attached sandbag weights at the outboard ends.

4.4 Winch Controls and Electrical Systems

During completion of the ACIB construction, contact was maintained with the staff at the construction site. Numerous questions were resolved in this manner. However, on March 19, 1982 a request was made to have a BACT representative travel to the shipyard to resolve problems with the winch control system. Upon arrival, the problem had been resolved by the contractor. On the next day the problem with the winch controls as well as problems with the D.C. power distribution system, the linear actuator position indicators, the fire alarm system and the cushion pressure meters were discussed. These problems were due to either the craft not being wired according to the drawings supplied by BACT or component failures. When these two situations were rectified all controls and systems operated as required.

4.5 Full Scale Trials

4.5.1 Seal System Tests Overland

The initial inflation and lift-off tests were conducted to insure that the seal system and lift system in general functioned correctly before the craft was moved off of the raised steel building foundation. BACT representatives were not present for these tests and the following comments referring to the seal system were obtained secondhand. They are included because of their pertinence to the main body of the report and to the conclusions.

At the first lift, the standard fingers all inflated correctly except that the craft was short on lift height and trimmed heavily bow down. This was put down to the notch fingers which appeared to be leaking severely and not closing off properly at the center. Eventually, material and attachment failures occurred in one or two locations. Further inspection revealed that the notch finger segments had not been assembled correctly. The large washers, called for on the drawing, under the rivets had been omitted, resulting in the rivets pulling through the finger material when pressure was applied. Sharp edges left on the trusses added further to the damage done to the fingers. Backing plates which were required at all locations of notch finger attachment to the truss had also been omitted.

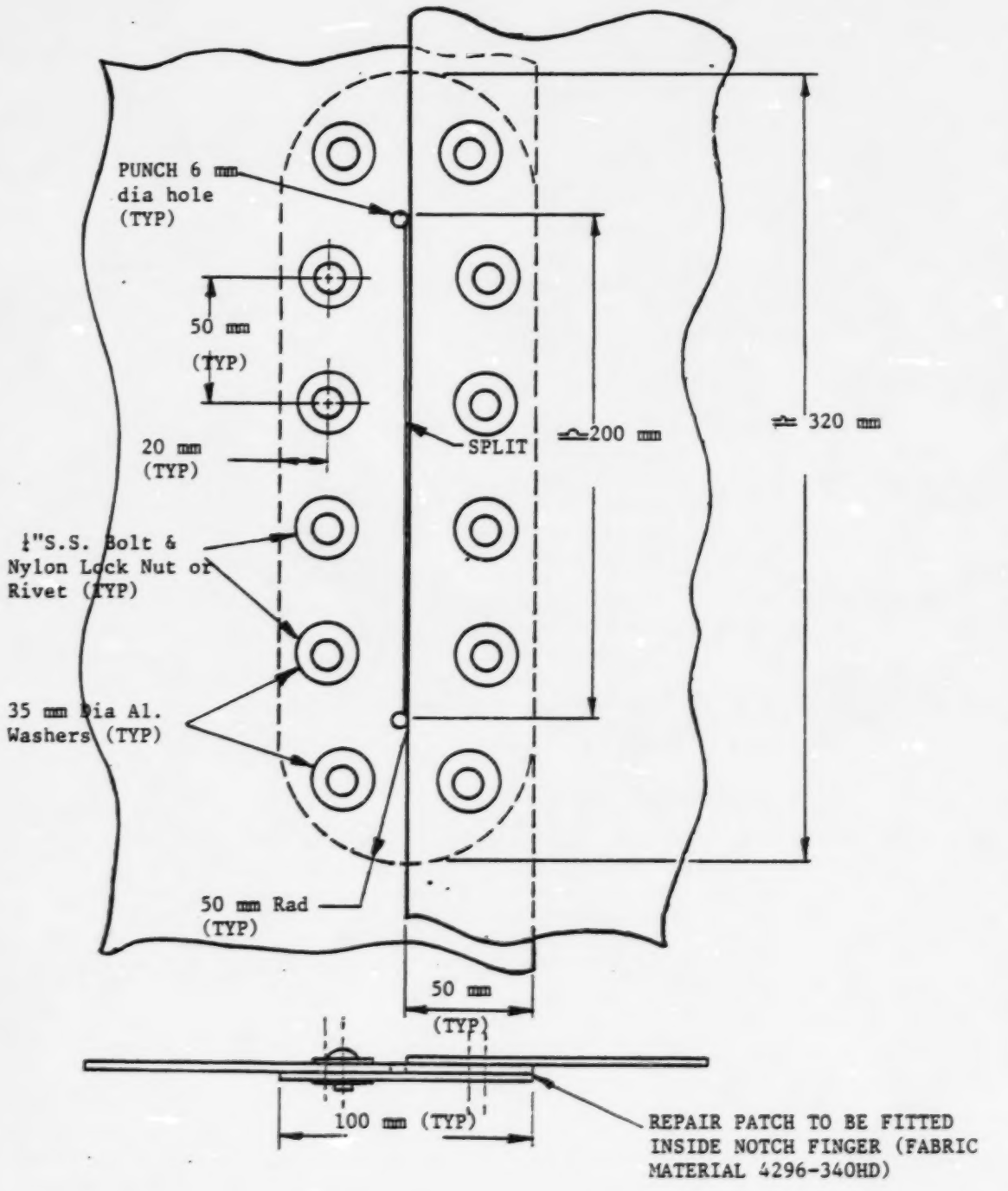


FIG. 4.3-1 TYPICAL NOTCH FINGER REPAIR

Apparently, it was not obvious to the test personnel that something was wrong with the notch finger geometry, because several tons of ballast blocks were loaded around the notch area and, after repairs to the notch fingers and attachments, the test was repeated. The finger material failed again and finally it was realized that the problem lay mainly in the location of the notch finger attachments along the trusses (see paragraph 4.3), and not the fore and aft trim. (Material strength of seal sample taken from the notch fingers proved to be almost 100% of the makers original specification). The notch fingers were rehung in approximately the correct position and for safety, it was decided to add a second layer of material (conveyer belting) over the top of the fingers in an arrangement of three panels per finger. To simplify the attachment to the trusses, one side of each finger was left unattached. While this arrangement considerably reduced the risk of material failure along the upper surface of the fingers (much like the inner tube in a tire), the partially unattached finger and somewhat discontinuous arrangement of the conveyer belting as well as the fact that the fingers were attached to the incorrect side of the trusses, allowed some local distortion to take place. The tendency for the nose of each finger to deflect upwards was accentuated. Eventually this effect was counteracted to some extent by the weight of the notch finger spray apron, attachment chains, and additional weights in the form of sandbags.

In an attempt to provide some protection for the inboard notch fingers over their area of possible contact with the ice-breaker hull, three additional sheets of conveyer belting (per side) were slung on chains from the notch sidewall. Deployment proved difficult in practice, and without bottom restraints they could not be maintained in position.

4.5.2 Ice-Breaking Trials

In this configuration, the lightweight mating trials with the ACIB and the Alexander Henry were completed satisfactorily. This cleared the way for the first of two heavyweight ice-breaking trials, and since the first of these was witnessed by two Bell representatives, this information is largely firsthand.

Transfer of the ACIB to the Alexander Henry appeared relatively simple although fairly time consuming. The crew had some difficulty in deploying the necessary restraint cables, but this operation could no doubt be streamlined in the future. The ACIB came on-cushion easily with a minimum of spray generation or pitching motion, and with the stem seals sealing against the hull reasonably well in spite of incorrect installation. This was apparent from two small open loops of material leaking to atmosphere. No such excess material should have been evident. The sealing capability of the notch finger spray apron left considerable room for improvement. Large triangular areas between the apron ends and the ship's hull, plus the tendency to blow outwards away from the ACIB, allowed large quantities of spray to escape, a fair proportion of which landed on the main deck of the Alexander Henry.

In spite of the various leaks and spray problems which continually soaked the crew, the ACIB appeared to ride well and moved with the ship without undue motion of its own, apart from a quite severe heave bounce. It was

learned that this characteristic, together with the lift diesel turbo whine, caused considerable annoyance and fatigue in the operating crew on the howdah.

For the first mile of the trial, continuous ice-breaking was achieved at approximately 3 knots. However, from this point on, conditioning became more difficult and progress could only be made by a series of charging maneuvers which resulted in 0.2/0.3 cable lengths of forward progress for every 6 or 7 minutes operation. Full speed operation, which resulted in 4 or 5 knots forward and astern, had to be reduced to half speed operation (approximately 2 knots) due to the ship's main hydraulic clutches overheating and leaking. Also, two cylinders out of ten on each main engine were not being charged fully so that the available power level was down some 20%. Progress across the ice sheet to open water, approximately 16 km (10 miles), was delayed by numerous ACIB refueling stops and a complete shutdown for the night watch.

Maximum ice thickness measured during the trip was 914 mm (36 inches) and continuous forward motion could be maintained with an ice thickness of approximately 760 mm (30 inches). While the latter agrees with the maximum cushion pressure of 840 mm (33 inches), the consistency of the ice which changed from fairly brittle at the start of the run to somewhat "spongey" towards the end, was a significant factor in determining whether the ice would break. This condition prevented breaking as wide a channel through the ice as was necessary for easy passage of the Alexander Henry. Wind direction was such that it caused the ice sheets to close the gap formed by the ice breaker, putting pressure on the ship's hull and adding to the load on the ship's engines and drive train.

Had the ACIB been ballasted to maximum weight, another 150/180 mm (6 or 7 inches) of cushion pressure could have been generated and had the Alexander Henry been able to generate full power, it is highly likely that ice could have been broken continuously throughout the two day trial. However, with the limited time available for further trials before the Spring thaw set in, it is possible that the limits would not have been determined and useful comparisons could not have been made with trials data from other air cushion ice-breakers.

Similarly, additional full scale performance information was obtained when towards the end of the first major trial, a tensioning cable was inadvertently slackened with the ACIB notched firmly and on-cushion. The combined rolling yawing motion that this induced in the ACIB overloaded the inboard ends of the hinged truss members and failed the finger attachment bolts. The incident was not serious in that the adjoining fingers more or less closed the gap and the ACIB remained on-cushion. This type of loading had not been allowed for in the design of the trusses. A deck level bumper should be considered in any future development work to limit ship insertion and to protect the inboard ends of the hinged trusses.

Early in the second ice-breaking trial, it is understood that a fairly serious failure occured in a number of standard bow finger attachments causing problems in returning the ACIB to base on-cushion. Without the full details of the failure mode, it is assumed that the repeated reversing

operations in order to ram thick ice had overloaded the bow fingers by scooping or snagging large blocks of ice. Since it is not practical to design an ACIB with sufficient ice-breaking capacity to meet all situations, it would appear that the addition of a non-scooping arrangement to all open fingers will have to be implemented.

4.5.3 Construction/Design Discrepancies, Systems

During the first ice-breaking trial several discrepancies between the designed system and the installed system were noticed.

The redesign to the fuel vents had not been carried out. A modification which would have elminated fuel spillage from the vent was not added and the fuel vents were still installed inside of the engine compartments. In order to vent the fuel vapour to the outside of the engine compartment a length of hose was clamped over each vent and routed to the outside. This was not as per the vent manufacturer's instructions which require unrestricted flow of the vent to atmosphere. None of the electrical bonding specified for the fuel lines had been installed.

While operating the winches during the overland trials, the condition detailed in section 3.5 occured; one hydraulic reservoir was returned to the other. To prevent this from recurring, an equalizer line was installed betwen the two reservoirs.

The "Fire Extinguish" pushbuttons at the engine enclosures had been omitted.

No connections had been made to the guide vane indicators. This prevented accurate monitoring of the orientation of the guide vanes and thus, their effect on fan performance.

During the trials the cushion pressure meters were inoperative. This prevented measurement of one of the main parameters.

5. CONCLUSIONS

5.1 Structural Components

The finger support trusses and strengthened carrousel structure, adequately support the fingers and transmit finger loads to the buoyancy tanks. However, as noted in Section 4.5.2 "Ice-breaking Trials", a line handling error resulted in an unanticipated side load at the inboard (hinged) ends of the truss members. This loading failed some finger attachment bolts. A deck level bumper, or other protection device, should be devised to protect the inboard ends of the trusses.

5.2 Notch Seal System

In developing and implementing the changes to the ACIB notch seal system to provide an ice-breaking capability for the winter season 1981/1982, the greatest concern was the possible problems associated with coupling and uncoupling the ACIB with the mothership. Model tests and calculations provided clear indications on the performance of the various components

of the notch seal, but only over-simplified representation of the matching process had been possible with the test rig set-up. The ACIB appeared to run up and down the ice-breaker bow without any trace of pitch trim problems caused by friction or snagging between the inboard notch fingers and the hull plating. It even proved possible to separate the two vessels while the ACIB remained on-cushion.

A problem did arise, however, in locating the two craft the correct distance apart at intermediate cushion heights and in the water-borne mode. In this condition, the pushing post rollers cannot maintain the correct separation of the two craft. Some solid means of providing an overriding stop during the intermediate conditions appears necessary to avoid overloading the inboard frames by the wedging action of the bow stem close to the inboard hinges.

With cost and scheduling difficulties involved, it was decided not to modify the inboard notch fingers to obtain a perfect seal against the ship's hull (see reference 1, page 33). However, after witnessing the trials, it is clear that this area needs special attention.

There will always be some point at which the ice becomes too thick to break. Then either the short charging maneuver or reversing into clear water, would risk the possibility of scooping, or snagging blocks of ice large enough to be capable of damaging and eventually destroying the bow fingers. In the light of trials experience, when this is believed to have occurred, it is apparent that some form of finger closure is required by the bow fingers in addition to those already fitted to the stern.

With the current notch seal design, it is difficult to ensure that the two important inboard notch fingers fully inflate around the bow of the ice-breaker. There is a tendency for the intermediate fingers to inflate first and overcrowd the inboard fingers, thus disturbing the fit of the stern seals around the bow. It is important, therefore, that full inflation is achieved every time in this area and some means of enforcing this condition is required.

It was generally concluded during the trials that the cushion planform and its orientation towards the direction of travel was not optimized for maximum ice-breaking efficiency. Without wishing to get involved in the pros and cons of the notch concept, it did appear that the relatively short period it took for the unbroken ice to pass under the side corners of the ACIB was having a detrimental effect on the overall ice-breaking capability. It may be argued that in spite of the fact that cushion air spreads out under the ice all around, and sometimes considerably beyond the ACIB, there must be, for any given speed, cushion pressure and ice conditions, a critical time period for the ice to break. Due to local ice fracture and cushion leakage to atmosphere through these areas, the blocks generally appeared to break off within, or very close to, the central confines of the cushion perimeter. Thus, it would be expected in severe conditions, that incomplete breakage might occur first towards the beam ends, which tend to project beyond the main cushion area. This behavior was observed towards the end of each short breaking run before the overall drag of the combined vessels became too high for any further progress. Increasing cushion pressure obviously

would help with highly flexible Spring ice, to ensure that the essential ingredient was present, i.e. that cushion pressure was sufficient to allow air to displace the water from under the ice in the vicinity of the ACIB. However, it is concluded that increasing the cushion length at the side extremities would have the dual effect of concentrating the area over which the cushion was able to act and to increase the time each section of cantilevered ice remained within the cushion.

Finally, it was concluded that the chosen method for supporting the existing notch fingers in the short term (1981/1982 winter) will, with suitable modification, provide an effective long-term solution to the problem, provided that the notch is necessary. At least the major questions have been answered and the method works. Changing over to the so called "soft" approach, a self-supporting notch seal system, while theoretically feasible, would require a fairly extensive and costly program of model and full scale testing to reach the stage where the current system is today. However, the soft seal would immediately become more attractive if it was found that notch penetration could be reduced to the point where it no longer became necessary to fill in the missing cushion area with the ACIB operating on its own.

5.3 Lift System

5.3.1 The ACIB lift system, as designed and as installed, is entirely adequate for the purpose intended.

5.3.2 The inlet guide vanes are useful only as a closure device for an inoperative fan.

5.3.3 Full design cushion flow can only be achieved on three engines, however, adequate flow should be available for operation on two engines in emergency conditions.

5.3.4 Every effort should be made to avoid residual cushion leakage through hull module joints and skirt attachments, etc.

5.4 Fuel System

"As installed" the fuel system does not meet the original contract (reference 2) design criteria nor does it comply with DOT certification requirements (reference 3). Fuel tanks as supplied do not have a large enough capacity to insure three hours of continuous engine operation at maximum continuous power. The fuel lines, which do not permit the required fuel flow rate, make it tedious to fill all of the tanks and in fact, due to the method of filling from one end only, make it difficult to fill the last tank. Fuel vents as installed will not operate properly if there is a restriction caused by a blockage in the added hose. Electrical bonding of the fuel line has been omitted.

These shortcomings in the fuel system all cause the ice-breaker to operate below design requirements and contribute to a hazardous operating condition.

5.5 Winch Controls

To the knowledge of Bell Aerospace, these controls, as installed, operated the winches as required.

5.6 Electrical System

While adequate for the first run trials of the ice-breaker, this system does require some improvement. (See recommendations 6.4).

5.7 General Comment

The instructions from TDC to make the ice-breaker operational with the minimum input of a new design and materials; specifically, to use as much of the existing materials and design as possible, resulted in some portions of the ice-breaker being built, to less than optinum design. Deviations by the installing contractor from the designs submitted and instructions given, led to additional problems. A combination of the above two items, contributed to the ice breaker not performing as well as predicted.

6. RECOMMENDATIONS

6.1 Seal System

Any recommendations for changes to the seal system depend upon the plans for the future of the HSL-533. Since these are not known at this juncture, it is assumed that the R & D program will continue with further development of the current design with the object of producing a fully operational system.

In this context, the recommendations are as follows in order of importance:

1. Reduce the included angle of the notch by an amount equal to two notch fingers, thereby eliminating the need for a pair of trusses.

2. Rework the remaining six trusses as follows:

   (a) Adjust the angle of the notch finger attachment line to conform to the orginal design.

   (b) Extend each frame approximately 610 mm (2 feet) and redesign the out-board seal attachment fittings to eliminate wrinkling tendencies and support all the end loads generated by the fingers.

   (c) Provide bonded bead/clamp fittings for the notch fingers and ensure that all the attachment patterns are properly rounded where they contact the seal.

   (d) Increase the size and holding power of the finger root fitting attachment.

3. Rework the remaining six notch fingers as follows:

(a) Modify the inboard fingers so that the current leakage area at the hull/seal/water interface is reduced.

(b) Carryout hot bonding repairs to all fingers and add molded doublers along the truss and notch side wall attachments. Also, provide protective doublers to the inboard finger adjacent to the ice breaker hull.

(c) Remove the entire conveyor belt support system.

(d) Reattach fingers to the modified trusses in the fully inflated geometry.

4. Rehang the notch finger spray aprons and attach to the standard apron with appropriate fittings.

5. Develop new method to improve spray suppression adjacent to the ship's hull.

6. Investigate the effects of holding one truss on each side against the ACIB notch side wall, on overall inflation and sealing with the ice-breaker mated. Develop practical means of operation, i.e. change-over to the un-mated mode.

7. Provide an upper level stop or bumper to control depth of insertion while on partial cushion.

8. Develop a heave bounce control system.

9. Rework the standard finger attachments to the Bell-proven design (BH 110 SES) which allows removal and replacement in the hullborne mode.

6.2 Fuel System

In order to meet the design requirements as well as DOT Certification requirements for the fuel system the following improvements are required.

6.2.1 Increase the size of the fuel fill lines to accomodate the fuel flow required to fill the system in the specified time.

6.2.2 Add an additional fuel tank to the ice-breaker and connect it into the fuel system. Size this tank so that the operational time requirements are achieved.

6.2.3 Insure that the vents on all tanks are installed properly.

6.2.4 Electrically bond all fuel lines to each other and the tanks, and ground the system to the main structure of the ice breaker.

6.2.5 Fill the fuel tanks from the centre of the fuel fill system to prevent any tank from being only partially filled.

6.3 Winch Controls

6.3.1 Presently the winch actuator controls are not "dead-man" type. This allows the possibility that a winch will continue reeling out (or in) if an operator drops the control unit. These controls should all be of the self-zeroing type in order to prevent damage to the winch system, the ice-breaker or the pushing ship.

6.3.2 Although an equalizing line has been added between the two hydraulic fluid reservoirs, either a larger line or conversion to a single reservoir would be preferrable to insure that one hydraulic system does not become starved of fluid.

6.4 Electrical System

While the electrical system is adequate for operation of the ACIB, there are some weaknesses which should be resolved to improve the electrics.

6.4.1 Both the "Emergency Stop" and "Extinguish" pushbuttons should operate through a latching relay which would maintain power on these systems until the fault causing their activiation has been corrected and the control system has been reset to the starting position. An alternate method of ensuring continued activation would be to use a latching palm button in place of both of these pushbuttons.

6.4.2 The signal from the Engine R.P.M. Sender to the Shipboard tachometer is sent through two unshielded wires in the Umbilical cables. This could cause interference which could not be properly deleted by the addition of a filter circuit. It would be preferable to send this information through a shielded 2-wire cable to insure a clean signal.

6.4.3 All of the control panels in the Wheelhouse are heated except the Central Winch Control Panel. There is no provision made to heat this panel. In the extreme temperatures in which this craft is to operate, this panel should be heated in a manner similar to the other panels, in order to insure correct control response.

6.4.4 In order to activate the solenoid valves in the winch hydraulic system, only an electrical pulse is needed. The type of control used applied a continuous current to the solenoid coil. It would be preferable to activate them with a momentary pulse.

6.4.5 All of the switch and relay contacts in the navigation lights are marginal in current carrying capacity. This could result in some of these contacts being welded shut during operation. As well, switch contacts and relay contacts in other locations could be damaged due to their being low in current carrying capacity. These should be replaced with contactors or switches of a larger rating.

APPENDIX

NOTCH FINGER LOADS ANALYSIS

The notch fingers are wedge-shaped in planform, with the wide end of the wedge outboard. Figure A-1 shows the approximate finger geometry. Two water levels are considered: on-cushion and off-cushion. The inboard end of the finger is open to the air cushion along the line ABCD when on-cushion. The critical section is at the outboard attachment to the trusses. The portion outboard of that point is subject to bending as an inflated beam from the loads generated by the cushion pressure. It at first appears that the off-cushion condition is more critical than the on-cushion condition, for two reasons: (1) there is a larger upward force while the balancing downward force on the finger's inward sloping face, when the craft is on-cushion, does not exist, and (2) the effective cross-section at the outboard attachment is reduced (fabric below water is assumed ineffective); however, the destabilizing moment of the radial pressure force is also reduced.

The normal cushion pressure is 10 kPa (1.45 PSI); the design maximum is 15.9 kPa (2.3 PSI). For structural analysis purposes, a factor of safety of 1.5 is used to obtain ultimate loads. Since both the stabilizing tension (due to the outward component of the pressure force) and the destabilizing forces are proportional to the cushion pressure, buckling or wrinkling of the fingers in bending does not depend on the magnitude of the cushion pressure in membrane analysis (which is assumed adequate here), but the loads to the attachments do. If the weight of the finger or other loads are to be considered, the magnitude of the cushion pressure is, of course, important.

Cross-section properties are determined as properties of a line rather than of an area, since the thickness of the fabric is small and is assumed constant and unimportant. Moments of inertia, I, are then in linear units cubed, and stresses kg/mm (lb./inch) rather than kg/square mm (lb./square inch). It is assumed that no effective radial (i.e., inboard-outboard) tension can exist below the level of BC in Figure A-1, at the critical cross-section, which thus is effectively an inverted U, although the area on which the pressure acts is almost twice as large with a correspondingly lower centroid. A membrane cannot resist compression, so that if a negative stress, indicating compression, is obtained, it means that wrinkling of the fabric occurs. The effective cross-section is changed by the wrinkle, but a post-wrinkling analysis and eventual buckling is beyond the scope of the present investigation.

The effect of the taper of the fingers is to reduce the resultant bending moment and hence the tendency for wrinkling to occur. It has been conservatively disregarded, however, if included a 25% reduction may be possible.

The analysis considers only the notch fingers with no ship in the notch. The condition with a ship in the notch yields somewhat higher cushion pressure and could be more critical for the fingers in terms of wrinkling and shear stresses.

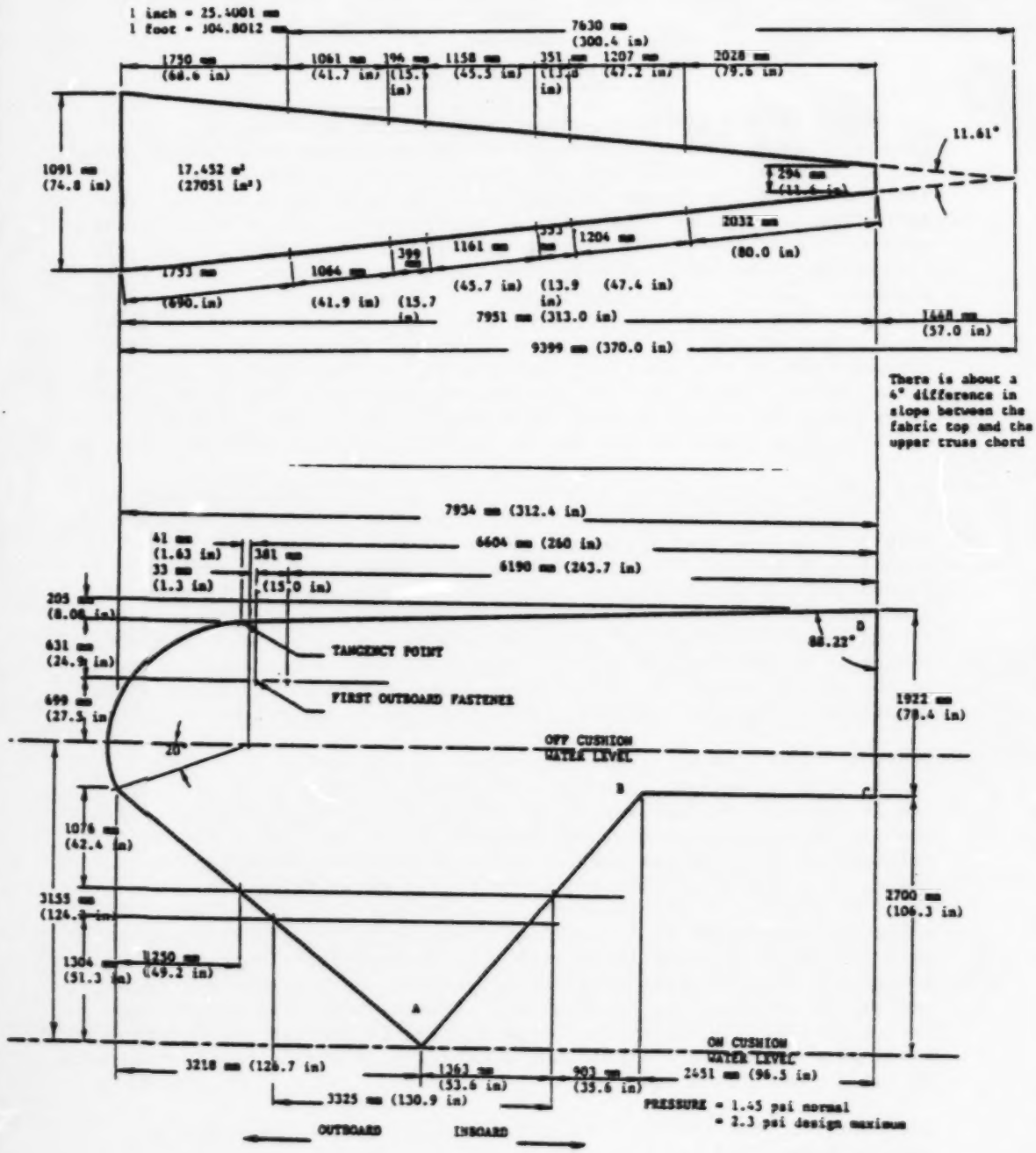


FIG. A-1 NOTCH FINGER GEOMETRY.

ON-CUSHION

Element	L	Y	L_Y	L_Y^2	I_o		A	Y	A_Y
⌒	96.04	72.28	6941.8	501753	8508	⌓	1468	30.57	44876
|	52.82	26.41	1395.0	36841	12280	□	5523	45.17	249474
|	52.82	26.41	1395.0	36841	12280	⌓	1468	30.57	44876
	201.68		9731.8	575435	33068		8459		
			$\bar{Y}_L$=48.25						$\bar{Y}_A$=7.66

$I = 33068 + 575435 - 201.68\ (48.25)^2$

$= 608503 - 469524 = 138979\ \text{in.}^3$

The tension normal to the cross-section is:

$T = 3.45\ (8459) = 29{,}184$ lb.

or $f_t = \frac{29184}{201.68} = 144.7$ lb./in.

$M_T = T(\bar{Y}_L - \bar{Y}_A)$

$= 29184\ (40.59) = 1{,}184{,}579$ in.-lb.

$\frac{Mc}{I} = \frac{1{,}184{,}579(52.82-48.25+30.57)}{138979} = 299.5$ lb./in.

Net f = 144.7 - 299.5 = -154.8 lb./in. (top fiber)

The negative sign indicates that the stress, f, is compressive, so that wrinkling occurs.

OFF-CUSHION. With the fingers off-cushion, the water level rises to the point marked "ctr. arc" in Fig. A-2 in the most critical case. Only the section above that point is effective.

Element	L	Y	L_Y	L_Y^2	I_o	A	Y	A_Y
⌒	96.04	54.37	5221.7	283904	8508	⌓ 1468	54.37	79815
|	34.91	17.46	609.5	10642	3545	□ 2134.4	17.46	37267
|	34.91	17.46	609.5	10642	3545	3602.4		117082
	165.86		6440.7	305188	15598			$\bar{Y}_A$=32.50
			$\bar{Y}_L$=38.83					

$I = 15{,}598 + 305{,}188 - 165.86(38.83)^2 = 70{,}707 \text{ in.}^3$

$T = 3.45\ (3602.4) = 12428 \text{ lb.}$

$$f_t = \frac{12428}{165.86} = 74.93 \text{ lb./in.}$$

$M_T = T(Y_L - Y_A) = 12428(38.83-32.50) = 78669 \text{ lb./in.}$

From Fig. B-1, the distance outboard to the extremity is 68.6 inches and the maximum width is 74.84 in. The minimum width is 61.14 in.

Moment M_V:

$$3.45\left[\frac{(68.6)^2}{2}(61.14) + (68.6)^2\left(\frac{2}{3}\right)(13.70)\right]$$

$M_V = 3.45\ (143861 + 42981) = 644605 \text{ in./lb.}$

Total Moment $= M_T + M_V = 78669 + 644605 = 723274 \text{ in.-lb.}$

Top fiber: $f_b = \frac{Mc}{I} = \frac{723{,}274\ (52.36 + 13.12 - 38.83)}{70707} = -272.6 \text{ lb./in.}$

$$f_b - f_t = 272.6 - 74.9 = -197.7 \text{ lb./in.}$$

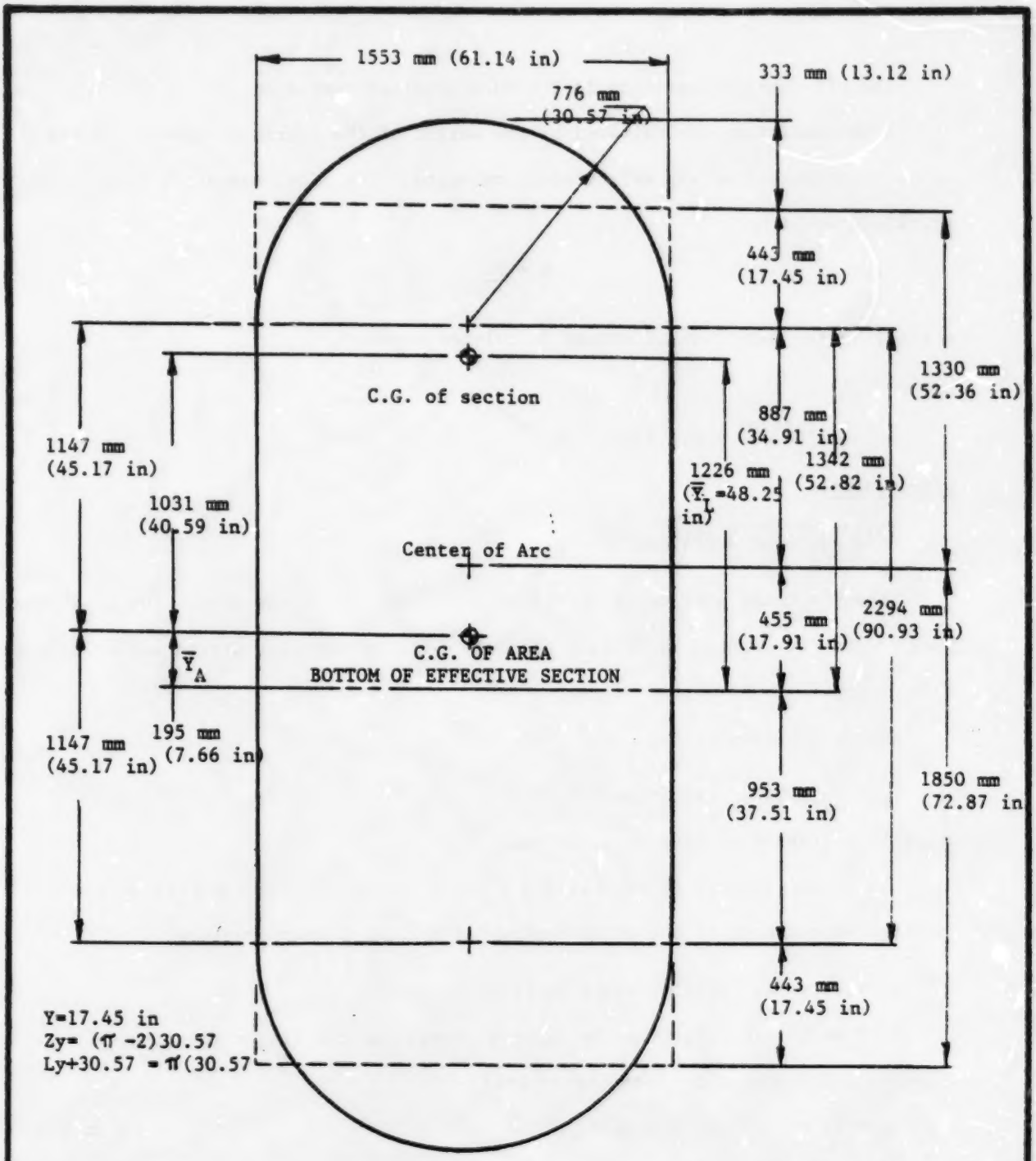


FIG. A-2 SECTION AT ATTACHMENT LOCATION ON DRAWING

The off-cushion condition is the more critical condition.

Both conditions are relieved by the weight of the fabric (neglected in the above calculation) or any weight added outboard. The added moment to eliminate wrinkling would be:

$$M = \frac{fI}{c}$$

where f is the magnitude of stress calculated above.

On-Cushion:

$$\frac{154.8\ (138979)}{35.14} = 612{,}235 \text{ in.-lb.}$$

Off-Cushion:

$$\frac{197.7\ (70707)}{26.65} = 524{,}531 \text{ in.-lb.}$$

Thus, it takes more weight to eliminate wrinkling in the on-cushion condition than in the off-cushion condition, although a higher negative stress was calculated off-cushion.

The weight required is:

$$\frac{612{,}235}{186{,}842} = 3.277 \text{ psi (with F.S. = 1.5)}$$

or, with no factor of safety, 2.185 psi.

The latter amounts to 68.6(2,185) = 149.9 lb./in. at the centroid of the finger area outboard of the attachments. At normal cushion pressure,

$\frac{1.45}{2.3}$ (149.9) = 94.5 lb./in. would be required.

If a weight is hung from the outer extremity of the finger mounting to W lb./in., its moment is (see Figure A-1).

$$M_W = 74.84\ W(68.6) = 5134\ W$$

Equating this to the on-cushion moment requirement to eliminate wrinkling of 612,235 in.-lb. leads to:

$$W = \frac{612{,}235}{5134} = 119.3 \text{ lb./in.}$$

With no factor of safety included, W = 79.5 lb./in. At normal (rather than design maximum) cushion pressure,

$$W - 79.5 \left(\frac{1.45}{2.3}\right) = 50.1 \text{ lb./in.}$$

The latter amounts to 3750 lb./finger (1700 Kg)

SHEAR. In the on-cushion mode, there is no vertical shear at the outboard attachment; the bending moment being entirely due to an unbalanced horizontal component of the cushion pressure force. Off-cushion, however the vertical shear is

$$68.6 \left[\frac{61.14 + 74.84}{2}\right] (3.45) = 16091 \text{ lb.} \quad (7299 \text{ Kg})$$

This load will tend to be taken by the outboard vertical row of ten fasteners, which will also tend to pick up considerably more than their share of the horizontal load, either on or off-cushion, because of the relatively low stiffness of the nylon fabric as compared with metal. Fabric reinforcement and additional fasteners will be necessary to prevent overload in all conditions.

CONCLUSIONS AND RECOMMENDATIONS

Additional weight over and above the 0.5 Kg/cm (2.8 lbs./in) provided by the existing anti-spray skirt amounting to approximately 16 Kg/cm (91.7 lbs/in) (but depending on its outboard location), may be necessary outside the outboard finger/truss attachment in order to prevent any tendency for the fingers to buckle upward at their outer ends. This undesirable situation could be alleviated, or perhaps eliminated, if the finger/truss attachments could be extended outward sufficiently far, preferably to the outboard ends of the fingers. The outer ends of the supporting trusses would require modification. Such redesign could also alleviate the high loads on the outer attachments. Analysis of possible wrinkling modes and fabric loads with the ship in the notch is also recommended as part of this work.

REFERENCES

(1) Design Review and Conceptual Design of Interim Notch Seal Air Cushion Ice-Breaking Bow HSL-533 (Montreal: Canadian Transportation Development Center Contract Nos. 4475/4478, Ref. D1460-163-14-2, Ref. D1460-163-14-2, Report No. 7575-950002, September 1981)

(2) Performance Specification for an Air Cushion Platform Ice-Breaking Attachment for Canadian Coast Guard Ships. (Ottawa: Air Cushion Vehicle Division, Canadian Coast Guard) para. 1.1.4 Design Parameters.

(3) Guide to DOT Certification Requirements for Non Self-Propelled Air Cushion Platforms, (Rev 2. Nov. 1978) para. 16.8.4

POOR

QUALITY

ORIGINAL